WWF Research Plan Table of Contents

Risk Management Research Plan For Wet Weather Flows

November 1996

National Risk Management Research Laboratory

U. S. Environmental Protection Agency

FOREWORD

This plan was prepared by the National Risk Management Research Laboratory (NRMRL) of EPA's Office of Research and Development (ORD) to guide wet weather flow (WWF) research for the next five years. It supports the priority research questions and needs of the Office of Water (OW) and has been peer-reviewed by two professional organizations engaged in WWF research. The group responsible for the Agency's WWF research is the Urban Watershed Management Branch (UWMB) of NRMRL's Water Supply and Water Resources Division (WSWRD). The plan will be updated jointly between OW and ORD annually.

In 1995, ORD initiated a reorganization to better manage its research programs. As part of this effort, a strategic approach was established for all ORD programs, founded on a risk assessment/risk management paradigm. A greater emphasis was also placed on WWF research issues to support better watershed management and improve control of nonpoint source (NPS) pollution. The focus of this plan is on the risk management aspects of WWF research. It addresses effects, exposure and risk assessment questions, and presents information on what is known in these areas, but emphasizes developing better risk-management decision support tools and WWF control technologies (both end-of-pipe and upstream pollutionprevention/nonstructural approaches).

ORD is also preparing strategic research plans in other areas; two that are closely related to WWF are the "Risk Management Research Plan for Ecosystem Restoration in Watersheds" (EPA, 1996a) and the "Contaminated Sediments Research Plan" (EPA, 1996b). Links with these plans will be established in the future. Further, as this research plan is implemented, NRMRL will continue to coordinate with its sister ORD organizations, including the National Center for Environmental Research and Quality Assurance (NCERQA), the National Exposure Research Laboratory (NERL), the National Health and

Environmental Effects Research Laboratory (NHEERL), and the National Center for Environmental Assessment (NCEA). The organizational charts for ORD and NRMRL are shown in Appendix A.

This research plan has two parts: strategic research directions and specific projects. The first part has five research areas: characterization and problem assessment, watershed management, toxic substance impacts and control, control technologies and infrastructure improvement. The second part identifies active and proposed projects supporting each research area and a sixth section, research assistance, that covers all other activities. Funding levels are shown in Part II and in Appendix B.

LIST OF SELECT ACRONYMS

ASCE
: American Society of Civil Engineers

BMP
: best management practice

BOD_5
: biochemical oxygen demand, five-day

CBEP
: community-based environmental protection

COD
: chemical oxygen demand

CSO
: combined-sewer overflow

CWA
: Clean Water Act

DWF
: dry-weather flow

EPA
: Environmental Protection Agency

ETI
: Environmental Technology Initiative

ETV
: Environmental Technology Verification

FACA
: Federal Advisory Committee Act

FBM
: flow balance method

I/I
: infiltration/inflow

MCTT
: multi-chambered treatment train

MS4

municipal separate storm sewer system

NPDES
: National Pollutant Discharge Elimination System

NPS
: nonpoint source

NCEA
: National Center for Environmental Assessment

NCERQA
: National Center for Environmental Research and Quality Assurance

NERL
: National Exposure Research Laboratory

NHEERL
: National Health and Environmental Effects Research Laboratory

NRMRL
: National Risk Management Research Laboratory

ORD
: Office of Research and Development

RII
: rain-induced infiltration

SLAMM
: Source Loading and Management Model

SSO
: sanitary-sewer overflow

SWMM
: Stormwater Management Model

USGS
: U.S. Geological Survey

UWMB
: Urban Watershed Management Branch

UWRRC
: Urban Water Resources Research Council

WERF
: Water Environment Research Foundation

WQS
: water quality standards

WSWRD
: Water Supply and Water Resources Division

WWF
: wet weather flow

WWTP
: wastewater treatment plant

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EXECUTIVE SUMMARY

This plan was prepared by the National Risk Management Research Laboratory (NRMRL) of EPA's Office of Research and Development (ORD) to guide the risk management aspects of urban wet weather flow (WWF) research for the next five years. There are three types of urban WWF discharges: combined-sewer overflow (CSO), stormwater and sanitary-sewer overflow (SSO); all are untreated discharges that occur during storm-flow events. WWFs have proven to generate a substantial amount of chemical, physical and biological stress to receiving waters. Control of WWF pollution is one of the top cleanup priority areas for the Agency. Problem constituents in WWF include visible matter, pathogenic microorganisms, oxygen-demanding materials, suspended solids, nutrients, and toxicants.

In 1995, ORD initiated a reorganization to better manage its research programs. As part of this, a strategic approach was established for all ORD programs, founded on a risk assessment/risk management paradigm. A greater emphasis was also placed on WWF research issues to support better watershed management and improve control of nonpoint source (NPS) pollution. The focus of this plan is on the risk management aspects of WWF research. It addresses effects, exposure and risk assessment questions, and presents information on what is known in these areas, but emphasizes developing better risk-management decision support tools and WWF control technologies (both end-of-pipe and upstream pollution prevention/nonstructural approaches).

National cost estimates have developed that address the cost to control contamination from the three sources of WWF. The projected costs for CSO pollution abatement are in excess of $40 to $50 billion. SSO pollution control is also estimated to be in the tens of billions of dollars. Stormwater management costs will even be higher than the combined costs of CSO and SSO abatement. Municipalities are finding it difficult to meet these high costs, so low-cost alternatives are a priority research area.

This research plan has two parts: strategic research directions and specific projects. There are five research areas: characterization and problem assessment, watershed management, toxic substances impacts and control, control technologies and infrastructure improvement. Active and proposed projects supporting each research area are included. Funding levels are shown in Part II and in Appendix B. The

plan was peer reviewed by the Urban Water Resources Research Council of the American Society of Civil Engineers (ASCE) and the Water Environment Research Foundation (WERF). Comments were also requested of over one hundred members of the Urban Wet Weather Flows Federal Advisory Committee and its subcommittees. This document incorporates changes that have been made as a result of these reviews.

CHARACTERIZATION AND PROBLEM ASSESSMENT

There are two research components in this area: (1) characterization of WWF andassociated receiving-water body impacts, and (2) development of characterization protocols. Knowledge of the receiving-water impacts resulting from WWF is a basis for determining the severity of problems and for determining appropriate levels of control. Studies have shown that the chemical, biological, and physical characteristics of WWF in urban areas negatively impact the aquatic ecosystems, health effects, stability, and aesthics of receiving waters. The WWF pollutants of most concern include: organics, pathogens, nutrients, pesticides, heavy metals, salts, and visable matter.

When determining the chemical and biological characteristics of WWF, analytical methods for sanitary wastewater are often used. For certain parameters, however, these methods are not directly applicable and specific WWF analyses are needed. Differences between WWF and sanitary wastewater that should be considered in determining the applicability of sanitary wastewater analytical methods to WWF include: WWF is intermittent and unsteady, where sanitary wastewater flow is constant; CSO consists of particles from stormwater in addition to those from sanitary wastewater, and these particles have different densities, sizes and biodegradability; and WWF contains nonenteric microorganisms that cannot be detected by using the bacterial indicators for fecal material used for analyzing sanitary wastewater.

The primary research question to be answered in this area is: "What tools are available to best measure the characteristics and impacts of WWFs?" Thirteen research projects are presented.

WATERSHED MANAGEMENT

Watershed management research includes two broad, closely related categories: protecting either ecological resources or source water areas. Watershed management research emphasizes strategies and alternatives to protect water resources. The urban component will dominate many watersheds. The watershed management strategy must define the watershed threshold limit, i.e., the level at which the cumulative discharges exceed the natural ability of the watershed to operate without loss of desired function. To select among the various options, planners must have the tools that will tell them the probable cost, effectiveness, time-lapse until effects are manifested, and longevity of the techniques. Collectively, these comprise the watershed decision support system. Distributing the information helps create a feedback loop to assist local governments to make incremental improvements.

Watershed management research will investigate techniques to reuse and reclaim

stormwater for beneficial purposes, defining the conditions when secondary uses are both desirable and economically possible. A truly holistic watershed management approach will include practical interaction with flood and erosion control, reuse and reclamation techniques, and infrastructure demands while protecting the watershed environment including source waters. This approach allows simultaneous pollution, flood, and erosion-sedimentation control designs and retrofits for the necessary retention and drainage facilities. It also requires community-level intervention using hard (structural) and soft (nonstructural) engineering approaches to protect or restore watersheds from chemical, physical, or biological stressors.

The primary research question to beanswered in this area is: "What effective watershed management strategies are available and how do communities select the most appropriate subset from these to match specific watershed needs?" Sixteen research projects are presented.

TOXIC SUBSTANCES IMPACTS AND CONTROL

Past studies indicate that urban stormwater runoff and CSO contain significant quantities of toxic substances; a number of the hazardous waste priority pollutants have been identified. Additional investigation of the significance of concentrations and quantities of toxic pollutants with regard to the health effects and ecosystem effects is required. Research must address source identification of toxic substances in urban WWF and the effectiveness of treatment technologies and pollution prevention measures that could be applicable to control toxic substance discharges. The long-term impacts of such toxic substances to ecological systems will also be addressed.

A significant proportion of toxic pollutants in urban stormwater is dissolved or colloidal in nature. In order to remove this form of pollution from high-intensity storm flows, development of effective, low-cost, and high-rate treatment processes both upstream and downstream of the storm runoff collection system will be needed. More effective, new flexible design approaches need to be developed for retrofitting and/or improving operations of conventional wastewater treatment plants and enhancing treatment efficiency to control toxic substances. The removal capabilities of newly developed treatment processes and the effectiveness of pollution preventionmethods for controlling these toxicants for meeting water-quality goals will be throughly evaluated. These evaluations will guide future development of more advanced techniques for minimizing toxicants from urban WWF.

The primary research question to be answered in this area is: " How can we effectively prevent and reduce toxic pollutant discharges to receiving waters of the urban watershed?" Five research projects are presented.

CONTROL TECHNOLOGIES

The options for pollution abatement in WWF can be implemented at the source by land management, in the collection system, offline by storage, or in a treatment plant. An integrated system that combines prevention, control, and treatment has often been found more effective than use of a treatment alone. In the case of treatment, many conventional processes are known to be inefficient for WWFs because of their high volume of flow over a short time period. More effort is needed regarding the effectiveness of nonstructural stormwater controls, such as public education, recycling, preventing illicit discharges, or catchbasin cleaning. Many municipalities are focusing on nonstructural controls rather than the more costly structural units. However, the municipalities are uncertain which controls are most effective.

A variety of high-rate treatment methods show a potential to handle WWF. A majority of them need to be demonstrated at full scale. These include such processes as: physical separation with and without addition of chemicals, constructed wetlands, biological treatment, and disinfection. Alltreatment processes, or their combinations, can be adjuncts to the existing wastewater treatment plant (WWTP) or can serve as remote satellite facilities at overflow points or upstream of the outfall. It may be cost-effective and practical to use WWF treatment technologies at the source of pollution upstream to prevent the pollutants from entering the drainage system and causing additional burden to the WWTP. An example of such an approach is upstream treatment of stormwater runoff from critical-source areas, such as parking lots, storage areas, and especially vehicular service stations. The area of storm-induced physical stressors on water bodies, e.g., high flow rates and heat changes, will be assessed and associated controls developed.

The primary research questions to be answered in this area are: "Is there a better way to design and operate sewerage systems given the concern for urban WWF pollution, and are there emerging technologies that can be used for treating WWF at a reasonable cost?" Thirty-six research projects are presented.

INFRASTRUCTURE IMPROVEMENT

The aging condition of our cities andan associated deterioration of infrastructure, such as buildings, highways, utility systems, water distribution systems, sewerage systems, leads to an emerging research area addressing both existing and new infrastructure. The costs are staggering; the national investment in sewers alone approaches $1.8 trillion. Excessive flow to the sewer system from infiltration/inflow (I/I) rob the capacity of the sewer system and negatively affect proper operation of the entire sewerage system; I/I has caused surcharging of sewers, WWTPs and pumping stations. Building connections to the street sewers or laterals can contribute as much as 70 to 80% of the infiltration load. Less expensive technologies are needed to detect leaks, forecast structural failure, construct I/I resistant sewer lines, and repair/rehabilitate sewers as well as other utility pipeline systems. The concept of reducing urban impervious cover from paved surfaces will also be included.

The primary research question to be answered in this area is: "What are the best approaches to rehabilitate existing and construct new sewer systems in urban settings?" Seven research projects are presented.

PART I - STRATEGIC RESEARCH DIRECTIONS

BACKGROUND

The urban WWF problem is caused by untreated discharges during storm events; there are both quality and quantity issues. Early drainage plans made no provisions to control the impacts from this type of pollution and physical stress from intensified flow rate and volume. The WWF comprises point source as well as diffuse nonpoint source (NPS) discharges.

There are three types of urban WWF discharges:

- **combined-sewer overflow (CSO)**, a mixture of storm drainage and municipal-industrial wastewater discharged from combined sewers or dry-weather flow (DWF) discharged from combined sewers due to clogged interceptors, inadequate interceptor capacity, or malfunctioning CSO regulators,

- **stormwater** from separate stormwater drainage systems in areas that are either sewered or unsewered, and

- **sanitary-sewer overflow (SSO)**, overflow and bypasses from sanitary-sewer systems resulting from stormwater and groundwater infiltration and/or inflow (I/I).

Further, there are diffuse NPS discharges that include agricultural, silvicultural, mining, rural, and open-space runoff. Septic systemdischarges associated with high groundwater levels or WWF surcharges of the groundwater system are also of concern.

The earliest sewers were built for collection and disposal of stormwater and, for convenience, emptied into the nearest watercourse. In later years, domestic or sanitary wastewater was put into these large storm drains, automatically converting them into combined sewers. Subsequently, combined sewers came into widespread use in communities because they represented a lower investment than the construction of separate storm and sanitary sewers.

When the problems of sanitary wastewater became recognized and the construction of wastewater treatment plants (WWTPs) commenced, engineers were confronted with how best to separate wet-from dry-weather flows to permit proper treatment of the sanitary portion. This was overcome by designing overflow structures called CSO regulators at selected points in the sewer system. These structures direct combined flows that exceed a predetermined multiple of mean DWF (or the intercepting sewer/WWTP capacity) directly into the receiving water body, whereas DWF is conveyed to the WWTP.

Overflow (or relief) points are also integral to separate sanitary sewerage systems. In designing the sanitary-sewerage system’s sewers and WWTPs, nominal allowances generally are made for stormwater and groundwater infiltration. Infiltration occurs due to joints and cracks in piping, which increases with pipe age. This problem of excessive flow entry is compounded by inappropriate and unauthorized stormwater connections, groundwater inflows and blockages. Reliefs in the separate sanitary system have beenused as an immediate and low-cost solution for these excessive flows. Studies conducted for EPA (Hayes, Seay, Mattern & Mattern, 1970; Metcalf and Eddy, 1971) found that separate systems with excessive I/I essentially act as combined-sewer systems.

THE PROBLEMS

Untreated overflows from combined and sanitary sewers have proven to be a substantial pollution source in terms of impact on the quality of the receiving water body. This is true for combined sewers even though the percentage of sanitary wastewater lost from these systems by overflow is small, on the order of 3 to 5% (Dobbins, 1962; Cywin and Rosenkranz, 1969). The storm path and collection system configurations have a pronounced influence on CSO quality, resulting in simultaneous discharge of mixtures of sanitary wastewater and stormwater at different points. These discharges may have sanitary pollutant concentrations varying from highly concentrated (raw-sanitary wastewater) to highly diluted depending on a system's adjustment to a particular storm pattern (Field and Fan, 1981). As indicated by the National Research Council: "Unlike sewage treatment plants and other point sources which discharge at relatively constant rates, nonpoint sources deliver pollutants in pulses linked to storm events. The quantity and type of pollutant contained in nonpoint sources depends on the human activity, the intensity and duration of precipitation, and the time between storms. The combination of the randomness of rainfall with the varying level of human activity makes controlling nonpoint sources relatively difficult" (NRC, 1993).

Pollution problems stemming from CSO, SSO and stormwater discharges are extensive throughout the United States, with the Northeast, Midwest, and Far West being the principal areas of concentration. Nationwide, approximately 1,100 municipalities have combined sewers, 85% of which are in eleven states serving 43 million people; there are more than 15,000 overflow points within these systems. SSOs occur in more than 1,000 municipalities and stormwater discharges occur in as many as 1.2 million municipal, industrial, commercial, institutional and retail sources.

Problem constituents in WWF include visible matter, infectious (pathogenic) microorganisms, oxygen-demanding materials, suspended solids, nutrients, and toxicants (e.g., heavy metals, pesticides, and petroleum hydrocarbons).

The average five-day biochemical oxygen demand (BOD_5) concentration in CSO is approximately one-half that of raw-sanitary wastewater. However, storm discharges can have a greater impact since they occur over a short time period, thereby shock loading the receiving water with high BOD_5 mass load. In addition, the volume of WWF discharged is high. Urban stormwater runoff flow rates from an average storm (0.1 in./h) are five to ten times greater than the DWF from the same area. Likewise, a common rainfall whose intensity is just ten times higher than the average (1.0 in./h) will produce WWF flow rates 50 to 100 times higher than DWF. Even separate stormwater is a significant source of pollution, typically characterized as having suspended solids concentrations equal to or greater than those of untreated sanitary wastewater. The bacterial and viral pollution problem fromWWF is also severe.

The average pollutant concentrations for urban stormwater runoff and CSO are compared to the typical background levels and to the sanitary wastewater levels in Table 1. The background data are the reported range of quality constituents from the U.S. Geological Survey (USGS) National Hydrologic Benchmark Networkthat was established to obtain a natural background. The ranges are average values across the country. The sanitary wastewater values represent common design values used to characterize a medium strength municipal wastewater. The values in this table for stormwater and CSO represent a random cross-section of sampling experience. The samples represent mixed urban areas for extended periods. (Lager et. al., 1977)

Table 1. Comparison of Pollutant Parameters [a] for Storm-Flow Discharges

	Suspended Solids	Volatile Suspended Solids	Bio-chemical Oxygen Demand (BOD_5)	Chemical Oxygen Demand (COD)	Kjeldahl nitrogen	Total nitrogen	Phosphate (PO_4-P)	Ortho-phosphate (OPO_4 - P)	Lead[d]	Fecal coliforms
Background levels	5-100	...	0.5-3	20	....	0.05-0.5 [b]	0.01-0.2 [c]	....	<0.1	....
Stormwater runoff	415	90	20	115	1.4	3-10	0.6	0.4	0.35	14 500
Combined sewer overflow	370	140	115	375	3.8	9-10	1.9	1.0	0.37	670 000
Sanitary wastewater	200	150	200	500	40	40	5	4	e	1,000,000

Notes: a. All values are in mg/L except fecal coliform which are in organisms/100 mL.

b. NO_3 as N.

c. Total phosphorus as P.

d. Prior to significantly lower unleaded gasoline usage.

e. No typical figure. Generally controlled by delivered water concentration or major

industrial source of metal.

Source: Lager et al, 1977.

A few municipal studies can serve to exemplify the WWF pollution problem.

- In Northampton, England, the total mass of BOD_5 emitted from CSO over a two-year period was approximately equal to the mass of BOD_5 emitted from the secondary WWTP effluent (Field and Struzeski, 1972). TheBOD_5 loadings during storm events were much more severe due to shock loading. The mass of suspended solids emitted in

CSO was three times that of the secondary effluent (Gameson and Davidson, 1962).

- A study (Dobbins, 1962) in Buffalo, N.Y. showed that 20 to 30% of the suspendedsolids in that domestic wastewater settled out, built up in the combined sewer system and were discharged during storms. This was due to the relatively poor flow characteristics of combined sewers during dry weather. A surge of flow caused by a rainstorm often purges the system, culminating in a release of solids. As a result, a large residual sanitary pollution load over that normally carried is discharged over a relatively short interval of time, producing shock loadings detrimental to receiving-water life.

- A study in Durham, N.C. (Bryan, 1971) demonstrated that the largest single source of pollution from an urban watershed was stormwater runoff. When compared to the raw municipal wastewaters, chemical oxygen demand (COD) in the urban stormwater runoff was equal to 91% of the raw municipal wastewater COD; the BOD_5 was 67%; and the suspended solids was 2000% that contained in the raw municipal wastewater. Urban stormwater runoff is a significant contributor to the overflow pollution load (in addition to the untreated domestic and industrial wastes carried in CSO). As stormwater drains from urban land areas, it picks up accumulated debris; animal droppings; eroded soil; tire and vehicular exhaust residue; air-pollution fallout; deicing compounds, pesticides and polychlorinated biphenyls, fertilizers and other chemical additives; decayed vegetation; heavy metals; and many other known and unknown contaminants.

- In another study (Field, 1990a), preliminary screening of CSO and stormwater from nine areas showed it contained approximately one half the 129 priority pollutants. Heavy metals were consistently found in allsamples. Polynuclear aromatic hydrocarbons from petroleum products were the most frequently detected organics followed, in order, by phthalate esters, aromatic hydrocarbons, halogenated hydrocarbons, and phenols. The Nationwide Urban Runoff Program (EPA, 1983) and other EPA studies (Jordan, 1984) also indicate that stormwater and CSO contain significant quantities of the priority pollutants, respectively.

National Cost Estimates

National cost estimates have been developed that address the cost to control contamination from the three sources of WWF. The projected costs for CSO pollution abatement are in excess of $40 to $50 billion. SSO pollution control is also estimated to be in the tens of billions of dollars. Stormwater pollution abatement cost will even be higher than the combined costs of CSO and SSO abatement. The American Public Works Association's report, Nationwide Costs to Implement BMPs (1992), identified possible capital costs of up to $407 billion and operation and maintenance costs of $542 billion to meet water quality standards for stormwater discharges. Municipalities are finding it difficult to meet these high costs, so low-cost alternatives are a priority research area. Addressing urban WWF in a coordinated and comprehensive manner will reduce its threat to water quality and minimize pollution control costs while providing State and municipal governments with greater flexibility to solve WWF problems.

DEFINITION OF THE URBAN WATERSHED

This plan focuses on the urban watershed, primarily because that is where the bulk of the population lives and the greatest impacts associated with water quality and hydrologic-hydraulic improvements will be felt. In contrast is the rural watershed, including wilderness areas far away from urban settings. Somewhere between is the urban fringe, or suburban area. The focus on urban areas, however, includes addressing the watershed as a whole, including urban fringe/suburban areas and, to an extent, rural areas. Other research programs, especially those of the Department of Agriculture and Department of Transportation, address the special issues related to rural and agricultural NPS runoff. This type of research is also being pursued in the Water Quality Management Branch of WSWRD and is part of the newly-created program in Ecosystem Restoration which fits across divisional programs in NRMRL. The Army Corps of Engineers addresses drainage system design with regard to flooding.

EPA and its views on the most effective methods to protect water resources are changing. EPA recognized the problems with “one-size-fits-all” or “command and control” regulations and the benefits that develop when stakeholders are part of the decision-making process. EPA also recognizes its mission goes beyond protecting water quality alone, and includes the ecosystem, the interaction of the aquatic system components, and the dependance of terrestrial systems on the aquatic environment. EPA is viewing its mission under the Clean Water Act (CWA), the Coastal Zone Recovery Act, the Safe Drinking Water Act, and other associated Congressional mandates as a broad mandate to protect the full watershed.

The idea of watershed protection is not new. As early as 1908, the Inland Waterways Commission proposed managing water resources at the watershed scale. Congress recognized the benefits of a watershed approach in 1965. The Water Resources Planning Act predates EPA but failed to accomplish the conceptual basin-wide planning envisioned. More recently, North Carolina reported on a promising method to manage the watershed scale at Watershed ‘93. South Carolina had executed a similar program and Washington and Delaware were developing the idea. About a dozen states have, or are, developing a watershed approach. Waste Load Allocation, allocation trading, and source controls are part of the watershed vision.

Somewhere in this process, lies the urban watershed. The urban watershed component is an arbitrarily drawn subset of a larger watershed loosely bound by topography. It is clearly an important part of the watershed holding most of the population and contributing pivotally to water quality problems. However, if urban areas eliminate all contributions to the watershed, the quality of the water entering the urban environment from upstream sources does not improve and

the water still may not meet desired standards or fulfill society’s intended use.

As a minimum, the urban watershed includes all contributions from the urban and urban fringe areas within the 405 Metropolitan Statistical Areas (MSAs) holding at least 50,000 people based on the 1990 census and proposed as the preferred option under President Clinton's Clean Water Initiative for implementing Phase II of the CWA. These include, at a minimum,MSA stormwater runoff, sanitary- and combined-sewer outfalls, and National Pollutant Discharge Elimination System (NPDES) permitted industrial and commercial outfalls. However, this minimum is not sufficient. For a reasonable interpretation, the urban watershed research must include the water entering the MSAs and the options specific to that water. As a minimum, it is necessary to include the entering water to adapt to the situations exemplified by total maximum daily load (TMDL) trading that allows upstream reductions to substitute for NPDES effluent. The urban watershed research must similarly recognize the probability of the expanding MSA geographic area. The national population is moving from the urban core to the surrounding areas. The fastest growing areas border estuaries and coasts.

Urban watersheds therefore include (1) all sources (point and nonpoint) originating within the Bureau of Census 405 MSAs considered urban or urban fringe, and (2) water entering the MSAs (surface and ground waters entering the MSAs from up-stream sources, source waters supplying the MSA population, and rain events).

REGULATORY AND POLICY BACKGROUND

Background

In 1972, under the authority of Public Law 92-500, the Federal Water Pollution Control Act, EPA created the NPDES. This was intended to control discharges to the Nation's waters from industrial, commercial, and municipal point sources; these discharges presented a threat to water qualityand public health. Initial efforts focused on traditional pollutant discharges from industrial manufacturing processes and municipal WWTPs.

Later amended to become the CWA, this law provides broad authority for EPA or States (authorized by EPA) to issue NPDES permits. Specific reporting requirements are established in the permits to require monitoring and reporting of discharges. The CWA establishes two types of standards for conditions in NPDES permits: technology-based standards and water quality-based standards. These standards are used to develop effluent limitations and special conditions in NPDES permits. Numeric effluent limitations establish pollutant concentration limits for effluents at the point of discharge. Section 402(a)(1) authorizes the inclusion of other types of conditions that are determined to be necessary, known as special conditions, in NPDES permits. Special conditions can include requirements for best management practices (BMPs) to control WWFs.

Since the implementation of the CWA requirements, EPA has begun to address nontraditional sources of pollution, such as those that result from WWF. The NPDES program currently requires permits for point sources, but not for NPSs.

Pollutants in WWF discharges from many sources remain largely uncontrolled. The EPA in both its 1992 National Water Quality Inventory (EPA, 1994a) and its 1995 Report to Congress (EPA, 1995a) cited pollution from WWF as the leading cause of water-quality impairment. WWF from both point and nonpoint sources is one of the largest remaining threats to water quality,aquatic life, and human health that exists today. The National Research Council (1992) concluded that correction of NPS pollution problems is a major priority to surface water protection and should be implemented a part of a large scale aquatic ecosystem program.

In its National Agenda for the Future, issued on December 30, 1994, two priority areas were cited by EPA in the water program:

- protect public health by ensuring that drinking water is safe

- protect the environment by improving WWF controls

This was reiterated by EPA in 1996 in the updated “National Water Program Agenda for the Future: 1996-1997".

EPA’s Initiative to Target Urban WWFs -the FACA Committee

To address WWF problems systematically, EPA recently began a major initiative targeting urban WWF pollution issues. As part of this effort, a series of stakeholder committees were formed under the Federal Advisory Committee Act (FACA). One group, the Urban Wet Weather Flows Advisory Committee, acts as a forum to identify and provide recommendations on how to address a range of issues associated with urban WWF discharges. The committee includes representatives of major stakeholders, including EPA, municipalities, States, industries, trade associations and environmental groups.

EPA’s CSO Control Policy

As indicated earlier, CSOs represent one of the major WWF pollution sources. Historically, however, the control of CSO has proven to be extremely complex and costly. This complexity stems partly from past difficulties in quantifying CSO impacts on receiving-water quality and the site-specific variability in CSO volume, frequency, and characteristics. In addition, control costs for communities with CSOs are high.

To address these challenges, EPA issued a National Combined Sewer Overflow Control Strategy on August 10, 1989 (EPA, 1989). This strategy reaffirmed that CSOs are point-source discharges subject to NPDES permit and the CWA requirements. The strategy recommended that all CSOs be identified and categorized according to their status of compliance with these requirements. It also set forth three objectives: ensure that if CSOs occur, they are only as a result of wet weather; bring all weather CSO discharge points (wet weather and dry weather) into compliance with the technology-based and water quality-based requirements of the CWA; and minimize the impacts of CSO on water quality, aquatic biota, and human health. In addition, the CSO Strategy charged all states to develop permitting strategies designed to reduce, eliminate, or control CSO.

Although the CSO Strategy was successful in focusing increased attention on CSO, it fell short in resolving many fundamental issues. In mid-1991, EPA initiated a process to accelerate implementation of the Strategy. The process included negotiations with representatives of the regulated community, State regulatoryagencies, and environmental groups. The initiative resulted in a CSO Control Policy (EPA, 1994b) which: provides guidance to NPDES permitting and enforcement authorities, State water quality standard (WQS) authorities, and NPDES permittees with CSO; ensures coordination among the appropriate parties in planning, selecting, designing, and implementing CSO management practices and controls to meet the requirements of the CWA; and ensures public involvement during the decision-making process. The CSO Control Policy contains provisions for developing appropriate, site-specific NPDES permit requirements for all combined-sewer systems that overflow due to wet-weather events. It also announces an enforcement initiative that requires the immediate elimination of overflows occurring during dry weather and ensures compliance with the remaining CWA requirements as soon as possible.

The CSO Control Policy contains the following four key principles to ensure that CSO controls are cost-effective and meet the requirements of the CWA:

- it provides clear levels of control presumed to meet appropriate health and environment objectives;

- it provides sufficient flexibility to municipalities, especially those that are financially disadvantaged, to consider the site-specific nature of CSO and to determine the most cost-effective means of reducing pollutants and meeting CWA objectives and requirements;

- it allows for a phased approach for implementation of CSO controls considering a community's financial capability;

- it allows for review and revision, as appropriate, of WQS and theirimplementation procedures when developing long-term CSO control plans to reflect the site-specific wet-weather impacts of CSO.

NPDES Permitting Program for Stormwater

Responding to the need for comprehensive NPDES requirements for stormwater point-source discharges, Congress amended the CWA in 1987 to require the EPA to establish phased NPDES requirements for stormwater discharges. These comprehensive requirements address permit applications, regulatory guidance, and management and treatment requirements. To implement these requirements, EPA published the initial Phase I Stormwater program permit application requirements to address certain categories of stormwater discharges associated with industrial activity and discharges from larger storm-sewer systems (located in 842 municipalities with populations of 100,000 or more) on November 16, 1990 (EPA, 1990).

One-hundred thirty thousand facilities have been identified as having stormwater discharge associated with industrial activity.

These include all stormwater discharges associated with industrial activity whether they discharge through municipal stormwater systems (whether they be small or large) or directly into waters of the United States. Discharges of stormwater to a sanitary-sewer system or to a WWTP are excluded. Facilities with stormwater discharges associated with industrial activity include: manufacturing facilities; construction operations disturbing five or more acres; hazardous waste treatment, storage, or disposal facilities; landfills; certain sewagetreatment plants; recycling facilities; power plants; mining operations; some oil and gas operations; airports, and certain other transportation facilities. Government-owned facilities must also comply. Stormwater discharge permits will provide a mechanism for monitoring the discharge of pollutants to waters of the United States and for establishing appropriate controls.

The Phase II Stormwater program potentially applies to smaller municipalities and is estimated to include as many as 1.1 million commercial, institutional, and retail sources, and 5,700 municipalities (urbanized areas of populations between 50,000 and 100,000). This is about ten times the number of facilities identified in Phase I. In 1995, EPA submitted a Report to Congress providing data, facts, and other information on sources to be considered under a Phase II Stormwater program (EPA, 1995a).

A FACA Urban WWFs Advisory Committee subcommittee is addressing issues associated with the development of regulations for the Stormwater Phase II program.

Legal Framework for Controlling SSOs

The CWA prohibits point-source discharges of pollutants to waters of the United States unless authorized by NPDES permit. Thus, unpermitted discharges from sanitary-sewer systems, e.g., SSOs, violate the CWA. This is true whether the discharge is directly to surface waters or indirectly through groundwater hydrologically connected to surface waters. Similarly, SSOs that drain through streets or other areas into storm sewers and then into waters of the United States violate the CWA unlessauthorized by NPDES permit. Finally, even SSOs that do not discharge to waters of the United States may be associated with NPDES permit violations. For example, 40 CFR 122.41(e) requires that NPDES permits include a provision for proper operation and maintenance of all treatment facilities and systems and controls installed or used by the permittee to comply with permit conditions. Poor operation and maintenance practices that result in SSO would violate such permit provisions.

SSOs may be specifically identified as subject to NPDES monitoring and reporting requirements. Operators of systems with SSOs that are not authorized by NPDES permit must either eliminate the discharge or submit a permit application (see 40 CFR 122.21(a)).

The CWA does not specify whether the technology-based standard for permits for SSO would be either: (1) the standard for publicly owned treatment works (POTW) or (2) the standard for all point-source discharge except those from POTW. For POTW, the CWA requires secondary treatment. For all other point-source discharges, the CWA has different requirements for different categories of pollutants: (1) best available technology economically achievable for toxic pollutants and nonconventional pollutants, and (2) best conventional pollutant control technology for conventional pollutants. Conveyances (e.g., sewers, pump stations) which transport wastewater to the WWTP are included in the regulatory definition of POTW. SSOs discharge from these types of conveyances. Therefore, one interpretation of the legal framework for controlling SSOs is that the POTW secondary treatment standardapplies. For combined sewer systems, EPA decided bypasses occur only from the process areas on the plant side of the headworks. Therefore, in the CSO context, secondary treatment requirements are only applicable to discharges from the WWTP, not discharges from CSO outfalls that occur before reaching the headworks of the treatment works. This interpretation was upheld by the court in Montgomery Environmental Coalition v. Costle, (1980). EPA has not clarified whether SSOs should be addressed in a similar or different manner than CSOs.

A FACA Urban WWFs Advisory Committee subcommittee was formed to provide recommendations on how to address issues associated with SSOs including deciding between sewer rehabilitation and treatment options to control SSO pollution.

NPS Requirements

Section 319 of the CWA requires States to develop NPS assessment and management programs. During FY96, EPA began to implement changes designed to strengthen the framework for State and national NPS management programs. The two primary areas of change will be establishing clear benchmarks for upgraded State NPS management programs and streamlining NPS grants administration for grant eligibility.

The specific NPS management program requirements to be implemented during FY96 are:

- complete review and approval of State coastal NPS programs with the EPA Regions and the National Oceanic and AtmosphericAdministration;

- work with agricultural and urban sectors to expand voluntary pollution prevention and reduction projects;

- work with Regions and States to upgrade State NPS programs; and

- publish and begin implementing new 319 program/grants guidance.

STRATEGIC RESEARCH DIRECTIONS

In 1995, EPA’s ORD initiated a reorganization aimed to better manage its research programs. As part of this, a strategic approach was established for all ORD programs, founded on a risk assessment/risk management paradigm. A greater emphasis was also placed on WWF research issues.

In the risk management paradigm, the risks associated with an environmental threat are first characterized (using hazard identification, dose-response assessment, and exposure assessments) and then managed through both regulatory programs and voluntary activities. Given limited resources, only significant risks that could have impacts over large populations or areas are addressed. The ORD strategic research approach has four components:

- effects research to determine the effects of stressors on humans and ecosystems,

- exposure research to measure and predict the extent to which humans and ecological resources are exposed to pollutants and other stressors, providing the basis for exposure assessment,

- risk assessment research to integrate hazard, dose-response, and exposure dataand models to produce risk characterizations, and

- risk management research to develop, evaluate, and disseminate effective tools and approaches for preventing or reducing current and anticipated risks to human health and the environment.

The focus of this Plan is on the risk management aspects of WWF research. It addresses effects, exposure, and risk assessment questions, and presents information on what is known in these areas, mainly in the context of developing better risk management decision-support

tools and WWF control technologies. Technologies being studied include both end-of-pipe and upstream pollution prevention, land and water management, and low-structurally intensive approaches.

There are four distinct areas of WWF research addressed by this Plan:

- characterization and problem assessment

- watershed management

- toxic substances impacts and control

- control technologies

A fifth area, infrastructure improvement, is also emerging as a critical WWF research category. These areas are discussed next in greater detail. Each section begins with a discussion on the state-of-the-knowledge and is followed by research questions and research needs that have been identified.

This Plan complements two other strategic research plans currently under preparation by ORD: Ecosystem Restoration and Contaminated Sediments. There are several distinct differences, however, between these plans. With regard to Ecosystem Restoration, while both plans willconsider the impacts of WWF on a watershed-wide basis, this Plan focuses on management (prevention and control) technologies while the Restoration plan centers on restoration of ecosystems. Typical WWF research projects that would fall under the Restoration Plan could include: ecosystem restoration techniques, stormwater impacts on stream stability, stream impacts from WWF velocity/shear forces and temperature changes, measuring the effectiveness of stream restoration, stream channels in rapidly developing watersheds, and WWF impacts on channel stability. Both plans, however, address water quality impacts, water quantity (hydraulic volumes, flowrate, temperatures) impacts, nonpoint sources, both the urban and urban fringe areas, and involve both structural and nonstructural remedies. Because of these similarities, the plans will be closely coordinated so that no duplication of effort occurs.

Research Area - Characterization and Problem Assessment

To achieve the goal of addressing pollution problems associated with WWF, i.e., managing the risk posed, WWF and the receiving-water bodies must first be thoroughly characterized. The research in this area has two components: (1) characterization of WWF and associated receiving-water body impacts, and (2) development of characterization protocols.

Knowledge of the receiving-water impacts resulting from WWF is a basis for determining the severity of problems and for determining appropriate levels of control. Research studies have shown that the chemical, biological, and physicalcharacteristics of WWF in urban areas negatively impact the aquatic ecosystems and health effects from receiving waters. Table 1 presents concentration characterization data for urban stormwater runoff and CSO. Other receiving-water characteristics of concern are the effects of WWF on contaminated sediments, dissolved oxygen, nutrient concentrations, heavy metals and organic compounds. WWF’s physical stressors also impact receiving-water quality and the ecosystem, although little research has assessed the relative effects in this area. Different types of receiving-water bodies are affected by different types and aspects of WWF, i.e., stormwater or SSO; chemical, biological, or physical impacts. For example, in some water bodies (lakes, estuaries), physical impacts may not be important; some receiving systems arise primarily in the urban areas (small streams) and are affected primarily by stormwater and some (larger systems) pass through the urban area and are subject to other forms of pollution problems, such as CSOs and SSOs.

There is some controversy concerning whether a direct cause-and-effect relationship can be established to characterize the impacts of WWF on water quality and quantity. The issue centers more on quality, since the quantity impacts (flooding, erosion, scouring, etc) are fairly obvious. This leads to a conclusion on the part of municipal officials that we shouldn't implement control measures unless a clear relationship can be demonstrated. EPA believes that there is a definite correlation between storm events and degradation of water bodies, associating both water quality and water quantity impacts, and has prioritized the improvement of WWF controls to be one of its top two waterprogram priorities. The common sense approach is pollution prevention, at the source, to prevent contamination from reaching the environment. The source control approach, using both management and structural means, is a common means of addressing environmental pollution; in air programs, for example, it is difficult to establish a direct cause-and-effect relationship between automobile exhausts and degradation of air quality, but we nonetheless insist on mandating source controls. Some difficulties with measuring receiving-water impacts of WWF are: (1) each situation is unique, in terms of watershed and runoff characteristics, (2) even within one area, there are extreme differences associated with each storm event since weather conditions are so variable, (3) there are variable reaction rates (e.g., BOD), variable flowrates and velocities, variable dilution rates, and (4) downstream confusion caused by WWF entries and tributaries, etc. This is markedly different from sanitary sewerage design. Recognizing that this is a significant issue, the Water Environment Research Federation (WERF) is developing a protocol for measuring WWF impacts. The EPA will work with WERF in this important effort.

The classic problem related to organic pollution of receiving waters is the consumption of instream oxygen by the bacterial and chemical breakdown of organic material. The resulting low level of oxygen destroys sensitive species of fish and aquatic organisms and may cause anaerobic conditions which produce objectionable end products (Field and Turkeltaub, 1981). Under certain conditions, storm runoff can govern the quality of receiving waters regardless of the level of DWF treatmentprovided. Based on national annual mass balance determinations, urban wet-weather oxygen demand loads are greater than the dry-weather loads from the same areas and ten times greater during storm-flow periods (Field, 1990a). Heaney et. al. (1980) found that worst-case conditions do not always occur during the low-flow periods following storms. Urban stormwater runoff effects on dissolved oxygen, especially associated with runoff sediments, may occur at times substantially different from the actual storm period (Field and Pitt, 1990).

Urban WWFs add significant amounts of toxic materials to sediments in receiving water bodies. In recent years, contaminated sediments have emerged as a major ecological and human health issue throughout the United States. There are direct acute and chronic toxic effects as well as a continuing source of persistent bioaccumulative toxic chemicals.

In 1994, EPA published the Contaminated Sediment Management Strategy (EPA, 1994c), the goals of which are: (1) to prevent additional contamination of sediments, (2) to restore contaminated sediment to support ecological and human health, (3) to allow for expeditious and environmentally sound disposal of dredged material, and (4) to develop methodologies to enhance the capability for assessment of sediment contaminants. The research needs for contaminated sediments fall into four areas: (1) determine the extent and severity of sediment contamination, (2) develop methods and collect data to assess the ecological exposure and effects of sediment contaminants, (3) develop and validate chemical-specific sediment quality criteria, and (4) develop and evaluate sedimentcleanup methods. Sediment generation and transport, on the land surface and within the urban drainage system, are two of the most fundamentally important and least understood phenomena related to urban water quality. We need to understand the source of sediment in urban areas as well as the deposition and scour of sediment in sewers and channels. What constituents are in the sediment? The research should address the hydrologic and hydraulic issues of generation and transport. Among other problems, we can't really model sediment very well, in part because of a lack of fundamental information on generation and transport. This conclusion extends to any constituents adsorbed to the sediment. Sediment research needs to include efforts to understand the transport of the kind of cohesive sediment found in combined sewers. Two contaminated sediment issues specific to WWF research are: (1) can the amount of sediment being washed into water bodies during storms be reduced and (2) how much does WWF contribute to the problem of contaminated sediment in comparison to other sources. These research areas are not discussed in this plan but will be addressed in the Agency's research plan on contaminated sediments.

Examples of heavy metal and nutrient accumulations in urban sediments are numerous (Field and Pitt, 1990). A common mechanism of polluted sediments affecting the water column in urban streams is resuspension of previously deposited material. Wilber and Hunter (1980) found that significant sediment enrichments of heavy metals in the lower Saddle River in New Jersey were affected by urbanization, compared with the more rural upper Saddle River. The increase in heavy metal sedimentconcentrations due to urbanization ranged from about a factor of three for zinc and copper to more than a factor of five for lead, chromium, and cadmium. Similar results were reported by Rolfe and Reinbold (1977), who found that lead concentrations were much higher in an urban stream (almost 400 ug/l) compared with rural streams near Champaign-Urbana, Illinois. They also found a greater diversity of plants and animals in the rural streams than in the urban streams.

Pitt and Bozeman (1982) reported the results of EPA's three-year monitoring study of Coyote Creek in San Jose, California. Short- and long-term sampling techniques were used to evaluate the effects of urban stormwater runoff on water quality, sediment properties, fish, macro-invertebrates, attached algae, and rooted aquatic vegetation. Information collected in this study indicated that the effects of organics and heavy metals in the water and in the polluted sediment were probably most responsible for much of the adverse biological conditions observed. Within the urban area streams, many constituents were found in significantly greater concentrations during wet weather than during dry weather (COD, organic nitrogen, and heavy metals --lead, zinc, copper, cadmium, mercury, iron, and nickel). Urban stream dissolved oxygen concentrations were about 20% less than in the rural stream.

The EPA's CSO Control Policy requires primary treatment (or equivalent) and disinfection where necessary. The growing awareness of the adverse environmental impacts associated with the chemical reaction products of chlorination, the traditional disinfection technique, has ledto increasingly restrictive residual chlorine requirements. Disinfection by chlorination often can only effectively disinfect the free floating or surface microorganisms due to the relatively short residence time of the WWF, and, depending on the degree of treatment required, may not be effective if microorganisms are contained in larger protective solids. Chlorination has limits which are a function of chemical demand ("chlorine demand") and microorganism occlusion by particles relative to chemical penetration. These limits are based on the concentration, size, content and morphology of wastewater particles; water chemistry;

contact time; mixing; and disinfectant dosage/intensity. Therefore, determination of these particle characteristics is necessary for WWF disinfection process design.

The disinfection requirement under the CSO Control Policy and the adverse impacts associated with chlorination are among the issues leading to the development of alternative methods of disinfection. These methods have problems similar to those of chlorine disinfection. Specifically, disinfection by UV-radiation of effluents containing high concentrations of relatively large protective suspended solids and organics has proven to be ineffective. The absorption of UV radiation by these substances attenuates the available UV energy and reduces the depth of penetration into the wastewater (Roeber and Hoot, 1975). This reduction in disinfection effectiveness is further compounded by microorganisms within relatively large particles experiencing little or no radiation as a result of the absorption of the radiation by the outer, protective layer.

Historically, the impacts of WWF onsurface water have been considered to a much greater extent than have those on groundwater. Only recently have WWF impacts on groundwater through both soil infiltration and groundwater-surface water interactions been considered. Pitt et al. (1994) reviewed the groundwater contamination literature as it relates to stormwater. Potential problem pollutants were identified, based on their mobility through the unsaturated soil zone above groundwater, their abundance in stormwater, and their treatability before discharge. This information was used together with earlier EPA research results to identify the possible sources of these potential problem pollutants. Recommendations were also made for stormwater soil infiltration guidelines in different areas and monitoring that should be conducted to evaluate a specific stormwater for its pote

PART II - WWF RESEARCH PROJECTS

This part of the Research Plan presents ongoing and proposed project descriptions along with their five-year resource allocations and scheduled outputs. These projects are presented according to the topic areas of: characterization and problem assessment; watershed management; toxic substances impacts and control, control technologies, infrastructure rehabilitation and research assistance. The descriptions are broad; more specific narratives with schedules of outputs will be prepared as the projects are funded and implemented. Additional projects may be suggested by others. Tables listing all of the projects by technology area are provided in Appendix B.

A major emphasis will be placed on the development of intramural capabilities including a laboratory and pilot-plant facilities. The WWF Program will also continue to identify and develop intramural/infrastructure projects which will arise during the course of this five-year plan due to the needs of the user community.

TECHNOLOGY TRANSFER

Results from the research conducted in the four technical areas will be the basis for numerous research and technology transfer outputs from this program, which will include peer-reviewed journal articles and books and state-of-the-art compendium, guidance, methodology/protocol, and planning/design user's manuals along with national/international conferences, seminars, and workshops. The integration of the technical needs of the end users and the development of these outputs will be critical to the success of the Program. An integrated research and technology transfer program will continually seek to link key research information to the needs of the end users. In some cases, results from research and other activities conducted by other public and private sector organizations will be incorporated into technology transfer products through cooperative projects.

Key technology transfer product user groups will likely include metropolitan sewage, stormwater control, and utility agencies, cities and towns, Federal and State regulators, environmental engineering consultants, watershed management associations, and others. To maintain close contact with these user groups, national/international organizations that represent these users will be relied on for input in identifying user needs and will be encouraged to participate in the development of technology transfer products. These organizations include the American Society of Civil Engineers' (ASCE's) Urban Water Resources Research Council, International Association of Hydraulic Research/International Association of Water Quality's Joint Committee on Urban Storm Drainage, Association of Metropolitan Sewerage Agencies, National League of Cities, Conference of Mayors, Water Environment Federation/Water Environment Research Foundation (WERF), American Public Works Association/American Public Works Association Research Foundation, National Association of Counties, International City Managers Association, National Association of Towns and Townships, American Geophysical Union-Hydrology Section, American Institute of Hydrology-Urban HydrologySection, and National Ground Water Association.

Technology transfer product types will be carefully selected to be the most efficient in meeting the needs of the users. Products will include traditional delivery mechanisms such as manuals and conferences, and more state-of-the-art electronic and PC-based products such as CD-ROM and Internet-based products.

Technology transfer plans will be developed on an annual basis to identify key user needs to be met and important research results to be delivered to users. These plans will be developed cooperatively by the UWMB and Technology Transfer Branch within NRMRL with the active participation of the OW, the Regions, States and other key client groups.

In an effort to outreach to the public and establish a central repository for research documents in the WWF area, the NRMRL will investigate establishment of a database system using the Internet to include:

- literature database, which would include abstracts of all pertinent WWF writings, with the most relevant documents highlighted;

- performance database, which would include summary tables of performance data (keyed to references) relative to WWF pollution prevention, BMP performance, control technology treatment efficiencies, capital and O&M costs, and inventories of municipal/industrial control systems;

- full text document database, which would include the key WWF documents in their entirety (initially public domain documents only) that could be searched online and downloaded to the user's PC;

- characteristics database, which would be used for model calibration and by similar urban areas for problem assessment and only contain WWF quality/quantity data which had been prescreened to meet high quality database acceptance criteria;

- access door to other databases;

- calendar of events;

- message center for WWF user groups; and

- bulletin board for posting important notes, new regulations, progress reports of research/program studies.

The intent would be to feature "one-stop shopping" for the WWF professional. This will be incorporated into the NRMRL database system currently underway.

COORDINATION WITH OTHERS

The Urban Watershed Management Branch (UWMB) of EPA’s NRMRL has the lead for implementing WWF research throughout ORD, in support of the OW program office and national needs. The branch will implement the WWF Program by collaborative teaming with OW and other NRMRL units (see Appendix A), including the: (1) Microbial Contaminants Control Branch to assess the microbial impact of WWF and determine better and truer indicators of publichealth risks and assess WWF disinfection technologies; (2) Treatment Technology Evaluation Branch for the development and evaluation of WWF treatment options; (3) Water Quality Management Branch for research on impacts and related control-decision modeling; (4) Subsurface Protection & Remediation Division and Air Pollution Prevention and Control Division for the development of strategies and models that interface stormwater with groundwater and air-pollution deposition, respectively; and (5) the Technology Transfer and Support Division for the development of technology transfer products, electronic media systems, and seminars. The WWF Program will also coordinate research with its sister ORD organizations (see Appendix A), including the National Center for Environmental Research and Quality Assurance, the NERL, the NHEERL, and the National Center for Environmental Assessment. Finally, the WWF Program will work to establish links with the Ecosystem Restoration and Contaminated Sediments Research Programs.

ORD is also working to establish other mechanisms for conducting high quality WWF research and making it available to the public. The WWF Program is already coordinating with the research programs of the Army Corps of Engineers' Water Resources Institute, the Water Environment Research Foundation (WERF) of the Water Environment Federation and the American Society of Civil Engineers’ (ASCE's) Urban Water Resources Research Council. These organizations are establishing various mechanisms to coordinate and transfer research from their efforts and those of other organizations including municipalities.

On the international front, the WWF Program is coordinating research with Environment Canada and the Joint Committee on Urban Storm Drainage of the International Association on Hydraulic Research/International Association on Water Quality. It will also participate in a workshop on WWF supported by a bilateral agreement between the EPA and Japan’s Ministry of Construction and is exchanging information with the United Kingdom, France, Australia, Taiwan, Singapore, Sweden, Switzerland and other countries..

PROJECTED WWF PROGRAM RESOURCES

The projected WWF Program resources are summarized in Table 2. In FY96, the program was built up in Edison, New Jersey to include approximately 8.0 person years. Additional personnel from other NRMRL units will be involved in the research. As current activities are phased down in other programs at Edison, additional manpower will be devoted to this research Table 2. Past and Projected NRMRL WWF Program Resources

FY	Person Years	Funding ($K)
1996	8	500
1997	12	2,834
1998	14	2,034*
1999	16	4,000
2000	16	4,000

* this decrease reflects a disinvestment of $800K being considered by the Agency for FY98.

area. By the end of FY96, the intramural effort in NRMRL will increase to 8 person years in the WWF area. In FY97 the Program will be at full strength (12 person years) with modest growth in succeeding years.

Wet weather flow research resources (financial and staff) are insufficient to support the full urban watershed research needs. UWMB will allocate research resources across the watershed to protect and restore ecology with a strong emphasis on water quality indicators directly affecting the intended societal use reflected under States' CWA 305 reporting. Early research effort will place more emphasis on urban-specific conditions with less resource allocation on entering water. UWMB does not envision emphasizing research efforts on drinking water but recognizes nonstructural protection tools implemented for source water protection transfer directly to other applications. The same physical processes govern the efficiency of a buffer strip installed along drinking water sources, urban or nonurban receiving waters. The science and engineering does not fundamentally change because of the application.

SPECIFIC PROJECTS

Specific projects to implement the WWF Research Plan are presented below. These are either ongoing, will be initiated in FY97, or will be initiated in later years. The projects are listed according to need, but many projects address several needs so there is overlap. Further, some needs are not yet addressed. The descriptions given are summaries of the scope of work associated with the project; these may change as the project is implemented. ORD and OW intend to provide quarterly progress reports for each project and make them available over the Internet.

The projects are funded by several mechanisms: through the NRMRL research program (either in-house using infrastructure funds or extramurally), through section 104(b)(3) of the CWA (either from OW or the Regions), as special projects Congressionally mandated, through EPA's Environmental Technology Initiative/Environmental Technology Verification program, as ORD/NCERQA grants, or as joint projects of mutual benefit.

Projects with NRMRL funding are led by NRMRL personnel. For projects with other sources of funding, NRMRL is working cooperatively with the lead organization, generally in the role of technical advisor. Projects receiving FY 97 NRMRL funding and ongoing projects are considered to have the highest priority. The FY97 projected funding is summarized in Appendix B.

This plan will be updated annually in a joint effort by ORD and OW. It is EPA's policy that all research funded be consistent with this plan. However, there will be projects in the WWF arena that are neither research, development or demonstration (e.g., training and outreach) that will be funded by the Agency but are not covered in this plan. Additional projects will be added in the area of 104b3 grants funded by EPA's Regional offices.

Over the coming years, ORD expects to strengthen its in-house research programs. To a great extent, competitive cooperative agreements will be the mechanism of favor in implementing this WWF Research Plan.

Research Area 1 - Characterization and Problem Assessment

Research Question

What are the characteristics of WWF and impacts on receiving-water bodies, and what tools are available to best measure them?

Research Need

Review, improve and develop monitoring methodologies and equipment to measure the characteristics and impacts, including pathogenicity, of WWFs.

Research Projects

1.1. Pathogen Detection

The project objective is to develop a suite of tests for determining the total diseaseproducing capacity of receivingwater bodies. This suite should detect harmful microorganisms originating from nonhuman sources and nonenteric pathogens that the current indicators do not signal, as well as fecalbased microorganisms which are detectable with current methods. One goal will be to produce a method which is quick, reliable, and inexpensive. UWMB will team with NHEERL and NERL to conduct epidemiological studies, as needed, to assist in the determination of indicators for total WWF pathogenic disease risks. This project will be funded by NRMRL.

1.2. Fecal Contamination

Current methods for detecting and quantifying human enteric viruses do not detect infectious hepatitis (hepatitis A virus (HAV)) and gastroenteritis (Norwalktype viruses). Current methods for detection and assay of bacterial pathogens are unreliable in detecting the Salmonella and enterohemorrhagic E. coli. Waterborne disease outbreaks caused by Cryptosporidium, Norwalk and hepatitis A viruses, and even Salmonella have occurred despite acceptably low levels of indicator bacteria. Reliable and practical methods for direct detection of enteric microbial pathogens and improved indicators for them in water are needed.

The goal of this project is to develop specific methods for direct detection of key enteric pathogens of human and animal fecal waste origin, and indicators for waterborne pathogens. Field studies will be done to evaluate improved fecal contamination detection methods for pathogens and candidate indicators associated with known human and animal fecal waste sources that impact water resources. Emphasis is placed on pathogen methods that detect and quantify infectious and viable organisms, and indicator methods that are predictive of pathogen presence and concentrations, distinguish human from animal fecal contamination, and identify sources of fecal contamination in water and watersheds. The goal is to develop methods for assessing control measures for water pollution, ecology of diseasecausing microbes in contaminated water, outbreaks of waterborne illness in humans, and performing quantitative risk assessments of waterborne enteric diseases. This project is funded through ORD's NCERQA Grant Program.

1.3. CSO Monitoring

This project will provide a methodology with widespread applicability for statistically calculating CSO quality data based on historical rainfall and WWTP quality data. The methodology will result in a low cost and expedient way of developing CSO quality data when compared to conventional monitoring methods. The WWF Program final report entitled, “Combined Sewer Overflow Characteristics from Treatment Plant Data” (EPA600/283/049), which uses WWTP influent and rainfall data to give CSO information as well as regression and/or derived distribution approaches similar to Tasker and Driver or DiToro and Driscoll, respectively, will be among the previous work used in the development of this project. Excessive simplification will be avoided; there is abundant meteorological and physical data (e.g., from GIS) to allow a better answer.

The extrapolation of inflow WWTP characteristics to CSO characteristics may not be meaningful. Clearly, it is for economic reasons that CSO monitoring is being investigated and it is likely that the results found from a project of this sort would be better than no CSO monitoring whatsoever. However, the character of CO quality is a function of the sewer system, the outlet control device, the service area and the rainfall characteristics. While it may be possible and even meaningful to derive a statistical relationship between CSO characteristics and inflow WWTP characteristics, this regressive relationship may be site-specific. Using this statistical model for other CSO systems may not be proper, thereby reducing the project's overall worthiness.

This project will also consider wet weather monitoring programs across the country to determine what is known about the design of wet weather monitoring provisions of a NPDES permit and the relationship of monitoring to the effectiveness of the stormwater management program. Based on the results of the investigations, a document may be prepared describing how to best design effective wet weather monitoring programs and data evaluation methodologies to judge the effectiveness of stormwater management programs. This project will be funded by NRMRL.

Research Need

Determine WWF receiving-water impacts and impaired beneficial uses that can be attributed to chemical, biological, and especially physical stressors.

Research Projects

1.4. Receiving Water Impacts

This project will finalize a draft user's guide for the assessment of WWF impacts (including toxicological) on receiving water. It will be published by CRC-Lewis, Inc., in FY97. This project is funded by NRMRL.

1.5. WWF Physical Stressors

WWF receiving-water impacts attributable from such physical stressors as high-flow velocity (high-shear force), temperature change and channel modification will be assessed resulting in the development of methodologies for preventing these impacts. To the extent possible, physical impacts on receiving waters will be documented, especially habitat destruction, sedimentation, and bank erosion. Stormwater quantity management techniques and effects on land at the headwaters of urban streams will be considered. This project will be funded by NRMRL.

1.6. Urban Landfill Pollution

This effort will comprise a joint project that is just being initiated with the USGS. The Norman landfill in Oklahoma has contaminated an alluvial aquifer adjacent to the Canadian River. NRMRLAda would join forces with the USGS to work toward the building of practical assessment techniques and tools to determine the influence of loading from a landfill to a surface water during WWF. This could be done through inhouse efforts, including site characterization, analytical chemistry and modeling. This project will be funded by NRMRL in support of funding by others.

1.7. Small Stream Impacts

This project will investigate percent imperviousness as a factor of receiving-water impairment and the effectiveness of BMPs at reducing receiving-water impairment. The use of stormwater environmental indicator tools will also be demonstrated. This project is funded by OW under its 104b3 Cooperative Agreement Program.

1.8. Large River Pollution

This project (cooperative agreement with the Ohio River Valley Water Sanitation Commission -ORSANCO) is developing a methodology to assess the wet-weather impacts of CSOs and other point and NPSs of pollution within a watershed on a large river (the Ohio River) and for evaluating the effectiveness of alternative CSO control measures. The project includes twelve tasks starting with the review of existing data and running through the development and implementation of dry- and wet-weather monitoring strategies and water quality modeling. The project is fully funded and will be completed in FY97. This project is funded by OW under its 104b3 Cooperative Agreement Program.

1.9. Evaluation of Health Risks

This project will develop and test a methodology to evaluate the human health and other environmental risks associated with separate SSOs. The methodology will enable a user to quantify the magnitude and frequency of overflows for a specific area using available information. In addition, the risks of these overflows will also be estimated based on specific water uses in an area. This research will focus on two primary aspects of the problem, specifically the persistence and fates of pathogens and toxicants. This project is funded by OW under its 104b3 CooperativeAgreement.

1.10. Water Body Impacts Model

The focus of this study is to develop a baseline assessment of the risks to aquatic life, and human health in the Duwamish River and Elliott Bay in King County, Seattle, WA. The project will result in the development of a calibrated model of the Duwamish River and Elliott Bay by which to predict the fate of contaminants discharged to these bodies of water. During this effort, the percent of total contaminants contributed by King County CSOs, separated stormwater systems, and secondary effluent discharged during peak-flow diversions will be estimated. Model inputs will be developed for chemicals and microorganisms from King County CSOs, separate storm drains, and secondary effluent to estimate the concentrations in the water column, sediment, and fish. This effort will assess the following: l) the baseline risk to aquatic life and humans who use the River and Bay; 2) the benefits to be gained by various levels of CSO control; and 3) the risks resulting from discharge of effluent to the Duwamish during peak flows. Data collection is scheduled to cover two wet-weather seasons. It is planned that work will conclude in the 1997 wet season. Assessment of risks and benefits will be completed at the end of 1997. This is a WERF Category 2 project funded by others.

1.11. Fate of Nitrogen Inputs

The nutrients moving from watersheds to estuaries is strongly conditioned by transformations taking place at the interface of rivers and tidal waters, the oligohaline zone. Nutrients will be up taken by planktonic algae, freshwater marshes, submerged macrophytes and sediment exchange. Current models of export to the coastal zone that deal with these transformations have difficulties quantifying nutrients at the ecosystem scale. The oligohaline reach is also a vital productive area for many highly bio-diversified species of animals. This zone is often a nursery area for commercial or recreational species which depend on the dynamic, production cycle of the oligohaline reach to support their high biomass and growth rates.

This project will run a test by introducing ^{15}N-enriched inorganic nitrogen to the oligohaline reach of the Parker River, the site of an ongoing Land Margin Ecosystem Research program. Previous wholesystem labeling experiments in forested watersheds, lakes and rivers have demonstrated the feasibility, power and cost effectiveness of the tracer addition approach. By adding the tracer to this reach, some questions about the transformations of materials from the watersheds as they enter tidal waters and influences of changing land use can be answered. This project is funded through ORD's NCERQA Grant Program.

1.12. Influences of Land Use

The project will study stream ecosystems that are influenced by land use. Biological monitoring of water quality will be measured with diversity and biotic indices that affect rates of community metabolism and cycling of nutrients. The objectives are to determine: (1) the relationship between current monitoring programs and ecosystem function as measured by rates of nutrient transport and metabolism, (2) variants among streams undergoing anthropogenic stresses, and (3) biological attributes to ecological function of the habitat, stream reach, and watershed landscaping.

Specifically, urban, suburban, agriculture and forested land uses around watersheds of the Chattahoochee River in Atlanta, Georgia, will be examined. Instead of studying watersheds from the cumulative NPS nutrient enrichment and episodic toxins, the data measured of stream ecosystem function will be compared and analyzed against hydrology, water quality, and biological community structure collected by the United States Geologic Survey under the National Water Quality Assessment program, and to riparian and watershed attributes at the basin scale using a geographical information system (GIS). The data are relevant for Federal natural resource management to embrace ecosystem of NPS pollution control, and invertebrate and vertebrate biological monitoring of ecosystems. This project is funded through ORD's NCERQA Grant Program.

Research Need

Assess the effectiveness of disinfection techniques using measurements that account for microorganisms occluded by particles.

Research Project

1.13. CSO Disinfection

This project will assess the effectiveness of various disinfection techniques for CSO. The technologies to be evaluated include rapid oxidants (e.g., ozonation, chlorine dioxide, perchloric acid) and UV disinfection. For disinfection with rapid oxidants, mixing and dosing (higher and/or two-stage) techniques will be evaluated. Techniques for measuring microorganism population that accounts for microorganisms that survive in the interstices of the larger organic particles andin the micro-fractures of soil grains (e.g., blending the samples, sonification) will be used in assessing disinfection effectiveness. This project will be funded by NRMRL.

Research Need

Evaluate the impact of and extent to which WWFs contribute to the contaminated sediment problem in the United States.

Research Project

The evaluation of the impacts of contaminated sediments will be addressed in EPA's Research Plan for Contaminated Sediments. The evaluation of the extent to which WWFs contribute to the problem will be addressed under this research plan. See Project 2.16.

Research Area 2 - Watershed Management

As with all research projects, there is overlap between the goals of the projects in watershed management; most projects address several research needs. Therefore, in this section the research needs are correlated with multiple projects, as shown below. This is followed by descriptions of the watershed management projects.

Research Question

What effective watershed management strategies are available and how do communities select the most appropriate subset from these to match specific watershed needs?

Research Need

Collate watershed management techniques with critical information (water quality impact, efficiency, total cost, sustainability, etc.) from research projects and demonstrations including stormwater reuse and BMPs for urban, urban fringe, agricultural (small and large farm), and riparian areas for the various ecoregions in the United States.

Projects 1.10, 1.12, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 2.10, 2.11, 2.12, 2.13, 2.14

Research Need

Evaluate public-domain open-code computer water flow and quality simulation models to predict and analyze the characteristics, impacts, and control options in a watershed.

Projects 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.13, 2.14

Research Need

Evaluate methods to predict ecologic (biologic, habitat, physiochemical, toxicological, benthic, etc.) indices and compare to measured (remote sensing and direct) observation.

Projects 1.5, 1.8, 2.3

Research Need

Define standard measurements, measurement procedures, data quality objectives and “compatible with•94" GIS format for data sharing across municipalities.

Projects 1.3, 1.5, 1.6, 1.7, 1.8, 1.9, 1.11, 1.12, 1.13, 2.3, 2.4, 2.13, 2.15

Research Need

Evaluate methods to predict quantity and routes of sediment migration (including channelization, stream bank and land surface erosion, and bottom scouring) and to affect control of contaminants associated with this migration.

Projects 1.6, 1.7, 1.8, 2.3

Research Need

Estimate the atmospheric contaminant contributions to a watershed by linking air quality measures to deposition.

Project 2.3, 2.9

Research Need

Demonstrate the methods to model interactions between and limit deleterious effects from stormwater runoff and source water (surface and subsurface).

Projects 2.1, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8

Research Need

Investigate the interaction between stormwater runoff and vadose zone soil, near-surface soil, groundwater, sediment and surface water.

Projects 2.1, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8

Project Descriptions

2.1 Watershed Management

Developing an all encompassing watershed strategy will be the cumulation of the fiveyear WWF research plan. This project will provide a method for assessing watershed management programs for improving WWF control, meeting watershed quality standards, and determining receivingwater and ecosystem impacts. Products will include: a user’s guide, computer models, databases, manuals, reports, journal articles, seminars, and workshops and training documents. This project should address: (1) the use of environmental indicators to determine the relative condition of urban streams and lakes, such as the Index of Biotic Integrity and Trophic Index, respectively, (2) whether groundwater standards can be used to test the suitability of groundwater for drinking, (3) determine the relative importance of flow changes, habitat degradation, and poor water quality to the condition of urban streams and lakes, (4) determine the achievable uses of urban streams and lakes in each ecoregion using environmental indicators, such as the Index of Biotic Integrity, (5) determine threshold values for factors, such as percent imperviousness and width of vegetative stream corridors, that degrade the quality of urban lakes and streams, (6) calibrate and verify urban runoff models capable of estimating pollutant loadings from different sources and predicting the effectiveness of different urban BMPs, (7) determine the runoff coefficients for grassed landscaped areas, (8) determine the importance of volume control to the integrity of different types of streams, (9) determine washoff rates of pollutants off of different types of urban surfaces, such as streets and lawns, and (10) determine the relationship between watershed protection techniques and the achievement of designated uses in the receiving waters.

The WWF Program will coordinate partnerships with organizations currently developing or implementing watershed management plans. Two noteworthy examples are the Chesapeake Bay watershed management plan, a multistate cooperative project that is including research on air deposition and New York City's Jamaica Bay watershed management plan. The Watershed Management Institute is beginning research to develop a relationship between watershed imperviousness and stormwater impacts on receiving waters for stream systems in the midAtlantic and arid western regions of the country. Some are leery of the goal here, however; placing pervious buffer strips, swales, detention or retention basins between the impervious area and the receiving water will completely change the flow and quality characteristics of the runoff. The attempt to develop simple cause-effect relationships could lead to municipalities setting maximum imperviousness limits, as was done in the City of Austin, Texas. The resulting battle between developers and the City was fierce and the City lost, resulting also in the loss of jurisdiction over the developments in question. Developing a user's guide will require solicitation identifying a municipal partner willing to implement a watershed-management plan. Funding would be required to support the municipal partner with intramural technical support (i.e., sampling, computer modeling, design, identifying pollution prevention techniques, communityawareness literature, monitoring program, and coordinating laboratory analysis with other partners). Background sampling must begin early in FY97 to achieve any measurable effects by the close of the planning period. The sampling program and maximum watershed size would depend on the availability and leveraging of funds.

Research is also needed on institutional needs associated with watershed management. These include public involvement/participation; development of regulations at the local/State/federal level; financing, statutory and case law; public "acceptance/rejection" issues; staffing needs to properly address stormwater management; how to assure that proper maintenance will occur (public vs. private maintenance is particularly important), and other subjects of this kind. Other issues include how multiple city and county governments can work together, equitable financing schemes, and prioritizing observed problems in a way acceptable to all key parties. This project will be funded by NRMRL.

2.2 New Urban Areas

The objective of this project is to develop a method to design integrated urban WWF collection, control, and treatment systems for newly urbanized watersheds or upstream additions to older systems using advanced concepts. Two decades of enormous changes in urban-storm-drainage practices have brought concerns for both flood and water pollution controls that require a new set of designs for collection-treatment. As more regulations are put in place requiring permits and treatment of separately sewered stormwater, the choice between installing a combined-sewer or sanitary- and separate-storm-sewer system becomes relevant again. Regardless of whether the sewer system is combined or separate, modifications to sewer and treatment designs can be incorporated into either system to reduce overflows. The new urban sewerage system design approaches will consider inline and off-system storage, real-time/inline water level/flow monitoring and routing for reducing direct overflow discharges. Larger diameter sewers with steeper slopes and narrow-bottom cross-sections can add storage capacity to the system while eliminating accumulation of DWF deposits. The design of new WWTPs should include treatment for WWF (i.e., CSO and SSO), and not just treatment of peak DWF.

EPA awarded two cooperative agreements: one to the University of Alabama at Birmingham (UAB) and one to the ASCE for study of WWF and pollutants transport in newly developed areas and for development of design methodologies that integrate WWF control, collection, and treatment systems for newly urbanizing watersheds. These projects will take three years to complete; the first step will be to review the current state-of the-art in controlling urban watershed WWF and then design methodologies will be developed.

This project is funded by OW under its 104b3 Cooperative Agreement.

2.3 Watershed Modeling

This project will begin by reviewing existing computer models related to urban (e.g., SWMM, SLAMM) and non-urban (e.g., HSPF, CREAMS, SWRRB) WWFs, developing a working definition of a watershed within the modeling context, and identifying controllable and uncontrollable watershed-contaminant sources. Computer watershed models are proposed to evaluate the effects of drainage, intersurface sources, stormwater runoff, pollutant controltechniques and various pollutant sources in a watershed. The results obtained from these computer models not only need to be validated but the model will need to be calibrated for each study effort. Any modeling techniques employed in these research projects are likely to be used as examples in future watershed investigations.

The project will emphasize public-domain open-code models and determine which models are compatible with the watershed approach. Each model has individual setup needs. This project will identify these needs and evaluate the sensitivity of model output to these needs to establish data quality objectives and define methods and formats for multiple community data sharing. These models will then be studied to determine how they can be integrated to (1) include all drainage (stormwater, CSOs, SSOs, and NPSs) and receiving waters, (2) interface surface stormwater runoff with groundwater and surface water, (3) include contaminated and non-contaminated sediment migration patterns, (4) evaluate human and ecologic risk from toxic substances and pathogens and include their treatment/disinfection efficiencies, (5) include control practices and pollution prevention effects, and (6) include atmospheric deposition. Improving the existing models will most likely require outside expertise and stateoftheart computer hardware and software requiring extramural funding. Teaming will be necessary with other ORD components and universities with expertise in the areas being studied. To assure the products meet the needs of the contractors and consultants, the project will include a workshop to assure these needs are included. In order for models to be accepted by potential users, verification data is needed. Collecting these data is a major effort including sampling, analysis, and review of historical records which has significant costs associated with it. In fact, in many cases the high cost of collecting these data are overwhelming and the models, no matter how valid, are never applied. The project will also consider development of a GIS approach for integrating land use data with environmental data to demonstrate how the conditions in the receiving water change as you change the land use activities. This project will be funded by NRMRL.

Some concerns relative to this project have been raised during the peer review process which will be addressed as this project proceeds. One reviewer indicated "I question the value of this project. Where will the product be used, where will we ever see a project with enough money to gather the data required to calibrate. Our ability to model physical/chemical/biological processes already far exceeds our resources to collect the data necessary to calibrate and verify them."

"The description states that public domain software will be reviewed. Because of lack of support for stormwater software development during the past 15 years in the U.S. and concurrent emerging interest in Australia, Canada and Europe much of the improvements in software have been made there. Even though much of this software is proprietary it would be worth evaluating it to see if it would be worth acquiring. Thus, we suggest including review of this newer software in the proposed research projects."

"If models are to be improved, we need information on the true sources of pollutants that appear in urban runoff, including the relative contributions from pervious and impervious areas. Land surface sources include pavement deterioration, automobiles, atmospheric fallout, erosion, fertilization, vegetation (e.g., leaves), etc. It is difficult to evaluate and improve water qualitymodels without fundamental research on the sources of pollutants that appear in the runoff. Additional research is also warranted on the “washoff” mechanism, e.g., relationship of washoff load with shear stress, rainfall energy and other hydraulic and hydrologic characteristics. All of this is in addition to the need for sediment-related research described above. Similar needs apply regarding how to model BMPs. We need to understand the fundamental removal mechanisms in order to include them in models. For example, a later research project (item 4.9) deals with riparian forest management. Riparian zones have been suggested as a BMP by many groups, including foresters. But how do we model their effects? Regarding models, prediction of water quantity is better than water quality, but there are still many areas that need improvement. One fundamental hydrologic issue is related to scale: we simulate large urban areas with input from a single raingage. What adjustments need to be made to account for spatial variability? This is especially important for continuous simulations. Many other important quantity modeling issues and needs could be listed. Finally, regarding models, support for model maintenance and updating is needed. The most useful models currently are those that have enjoyed some level of federal (e.g., HEC) and/or quasi-voluntary support (most of the current EPA models). But the latter models could be (and need to be) so much better with a modest, but firm and continuous level of federal financial support. There is also a need for better user interfaces for most of the EPA NPS models currently used, especially SWMM."

"These models are of another technological era and, while useful, may not be the best tools for the future of WWF engineering. The time and effort required to achieve these many linkages may not be worth the benefits received. Perhaps the WWF research plan should look to the ongoing work performed at the USACE HEC. While HEC's mission is different from that of the EPA's, the modeling philosophy may not be far removed. HEC has essentially re-written the computer code of many of its more useful models, retaining the aspects of each that have proven effective from previous versions, while adding many new features. Included in these new features (besides a windows front end) are seamless linkages between models. If the more useful WWF models were identified, along with the aspects of each that have proven useful over the past 25 years, perhaps a more useful tool for the future could be developed. While a major effort, the idea should be investigated within this research area."

2.4 Source Water Protection

This project will demonstrate watershed-scale innovative methodologies to control stormwater runoff and diffuse contaminant sources from urban, agricultural, and forested areas specifically for the protection and enhancement of the quality of source waters. A cooperative effort is being considered between EPA, New York State and New York City as part of the New York City Watershed Protection Program proposed under S17765 funded at $105 M ($15.0 M/FY for seven FYs beginning in FY97). The UWMB WWF Program may collaborate with city, State, and EPA personnel to develop a research, development, and demonstration project(s). This multiple part project would include comprehensive monitoring and surveillance (including GIS) and coordinated modeling to plan, design and implement low and non-structurally intensive watershed controls. It may also address development and evaluation of protocols for assessing watershed controls. The controls of interest would be significantly less expensive than the alternatively proposed largescale filtration facilities. The controls would include pollution prevention practices, (e.g., material substitution using lessor nontoxic types and controlled useof environmentally harmful chemicals), upstream biofiltration practices (e.g., grass swales, buffer strips for pollutant quality and flow attenuation) induced infiltration ponds and trenches; upstream hotspot pollutant source treatment (e.g., multi-chambered treatment trains at vehicular service stations); upstream impoundments and ponds; flow diversion and drainage modifications; and wetlands treatment.

Control effectiveness will be measured by (1) before and after implementation comparison of reservoir impacts, (2) influent and effluent efficiency evaluation for specific processes for enhanced watershed management modeling impacts predictions, and (3) sidebyside comparisons of controls against no controls. This project will be funded by NRMRL in support of funding by others.

2.5 Stormwater Reuse

Develop subpotable reuse techniques and strategies for WWFs. Reuse capabilities to be investigated include waters for: industrial cooling and processing; irrigation; aesthetic and recreational ponds; and land application of sludges. This project will be funded by NRMRL.

2.6 Stormwater-Groundwater Interactions

This project will close the gap in the water cycle by interfacing surface water, particularly stormwater runoff with groundwater. Research has not adequately investigated toxicant and pollutant routing to groundwater. Natural and promoted stormwater infiltrating the soil contains contaminants that can adversely affect groundwater. The same contaminants in surface flows degrade surface waters. Using conventional infiltration practices to treat and reduce stormwater runoff may be inappropriate if the effects on this water impair groundwater quality. A potential research investigating tool for WWFs between the surface and subsurface is initially finger-printing water isotopes in a watershed during storm events.

Sediment migration is a serious consideration at the watershed scale. Accumulation and depletion can destroy habitat. Stream bank erosion and bottom scouring reduce sinuosity, ripple-pool series, etc. that can shorten residence time, increase water temperature, decrease dissolved oxygen, and otherwise reduce the assimilative capacity of the receiving waters. Sediment control in channels, marinas, piers, and ports resulting from bank erosion, bottom scouring, and land surface erosion is expensive. The problems are amplified when the sediment is contaminated. Research efforts will examine predictive tools and control practices.

Generating a more complete understanding of the groundwater connections to surface water is critical to completing the understanding of the water cycle, contaminant transport, and source water protection. This project will interface stormwater models containing untreated and treated runoff vectors with subsurface and groundwater models. Furthermore, it will interface subsurface models with surface water models and related impacts assessments.

In a related project proposed for NRMRL internal grant funding by the Water Quality Management Branch naturally-occurring isotopes ^{18}O, ^{2}H, and ^{3}H will be used with selected chemical parameters to describe the components, pathways, and residence time of subsurface WWF discharging into surface receiving waters. A small hill slope adjacent to a nontidal streamwill be instrumented for time-series measurements in the vadose and saturated zones to produce a time-variant model explaining the water exchange.

Advances in stable isotope mass spectrometry enable tracing storm-induced infiltration through the water column to the receiving water in appropriately instrumented field sites. We plan to initially focus on measuring water molecule isotopes followed by a wider array of isotopes.

This work will identify pathways and residence times for WWF associated with receiving waters. It will then couple the isotopic tracer results with an improved catchment-scale and mass balance model that relate isotopic measurements and hygrometric parameters of WWF.

Since some receiving waters in urban watersheds are associated with brownfields, determining the fate of contaminated waters resulting from rain events on brownfields may be possible (variably flushed into receiving waters during storm events, infiltrate toward the regional water table, rejoin surface runoff, or remain perched for years). Performance assessment of storm flow abatement methods involving infiltration may be enhanced by understanding subsurface runoff mechanisms.

These objectives then will attempt to answer: (1) Under multiple land uses in an urban watershed, can isotopes discriminate subsurface storm flow from direct surface runoff resulting from WWFs? (2) Does subsurface storm flow contribute significantly to receiving waters? (3) Can residence times or turnover times be estimated for shallow subsurface brownfield waters? (4) Is shallow contaminated groundwater regularly flushed from storm events, infiltrate toward the water table, or remain perched for long periods? (5) Can isotopic techniques help performance evaluation of source controls and collection system controls for abating CSOs? This project will be funded by NRMRL.

2.7 Natural Attenuation

This project investigates the hypothesis that natural attenuation in the vadose zone and saturated zone mitigates unpreventable pollution deposited and transported by WWFs. Through literature and data collection, review, and analysis. and through inhouse, extramural, and cooperative research and monitoring efforts, key WWF scenarios where the hypothesis is true, false, or uncertain will be identified and characterized. This project will provide information, data, and critical analyses to support decisions about the applicability and effectiveness of natural attenuation against other aggressive and expensive approaches for detoxifying or immobilizing WWF transported pollution. This project will be funded by NRMRL.

2.8 Vadose Zone

Current vadose zone models assume steady state flow with rainfall events being incorporated as an annual average input. It is necessary to incorporate transient rainfall events resulting in surface water drainage to evaluate the influence on vadose zone chemical transport. Channeling of runoff into vegetated areas to reduce loading to surface-water bodies may generate large transient vadose zone fluxes and associated rapid transport of contaminants into groundwaters or from groundwater to discharge zones. The importance of these phenomena need to be evaluatedfor specific WWF problems, rather than accepting the convention assumption of steady flow. After evaluation, appropriate incorporation of transient vadose zone models with surface and subsurface water models can be made. This would tie well into current efforts for the drinking water research area. This project will be funded by NRMRL.

2.9 Atmospheric Deposition

Atmospheric deposition may be a significant contributor of organic (PCBs, PAHs, etc.) and inorganic (lead, zinc, etc) contaminants to the total watershed load beyond the control of the Community Based Environmental Protection communities. This project will begin by reviewing the sulfur deposition (as acid rain) in the model of acidification of groundwater in catchments (MAGIC), in collaboration with the air research division of NRMRL. EPA used this model in the Direct/Delayed Response Project assessing different deposition scenarios on 200 watersheds in the eastern United States. Follow on efforts will review and monitor the differing nitrogen deposition projects within EPA’s National Estuary Program in Tampa Bay, Florida and various other pollutants deposited from the atmosphere. Integrated relationships will be made between air pollution and associated controls and their contribution to stormwater pollution. The results of these reviews will direct outyear research projects. This project will be funded by NRMRL.

2.10 Mill Creek Watershed Plan

The purpose of this project is to develop an integrated watershed-management plan to assess and control CSOs and other pollution sources within the Mill Creek Watershed in Ohio. The plan will establish a process and develop decision criteria for selecting appropriate and costeffective WWF controls that provide longterm improvements in the watershed. The plan will also identify and resolve barriers (e.g., institutional, financial, legal, etc.) to implementing a consensus plan for resolving the complex pollution and ecosystem problems in the watershed. The ultimate goal of the project is to achieve communitywide consensus on an integrated implementation plan for the attainment of water quality and ecosystem goals. This project is funded by OW under its 104b3 Cooperative Agreement Program.

2.11 Catoma Creek Watershed Plan

The purpose of this grant is to implement a comprehensive management plan for improving water quality by controlling SSOs and other wet-weather pollution in the Catoma Creek Watershed in Alabama. The plan will focus on the longterm control of pollution sources in the watershed and the formulation of alternative strategies to address these sources. The plan will also bring about a coordinated decision-making process for addressing required action to achieve water quality improvements throughout the watershed and will provide periodic evaluation of the plan’s effectiveness. This project is funded by OW under its 104b3 Cooperative Agreement.

2.12 Stormwater Control/Impacts

The project goal is to demonstrate the implementation of innovative stormwater control practices and monitor the biological and waterquality improvements of the receiving water. Missing in current stormwater programs is a demonstration of the benefits, on a systemwide basis, of retrofitted or new controls. Past research efforts and demonstration projects have examined water pollutant discharge reductions associated with specific control practices. Some also examined receiving-water problems associated with untreated stormwater. This project will develop anddemonstrate "criticalsource area controls" and will measure the receiving-water response to retrofitted controls in a developed watershed. This project is funded by OW under its 104b3 Cooperative Agreement.

2.13 Watershed Model - Case Study

This project would be part of the overall effort in UWMB proposal "Watershed Management". Comprehensive watershed modeling will attempt to combine the EPA SWMM/HSPF surface watershed models with the EPA WhAEM/USGS MODFLOW groundwater models to represent urban baseflow and stormwater response, including pollutant transport. The Anacostia River ultimately flows into the Potomac River and the Chesapeake Bay. The river is listed by the White House Task Force on Ecosystem Management among the its seven priority areas and is an important watershed within the EPA Chesapeake Bay Program. A coordinated research project would need to be developed between the NRMRLAda and its cooperators for the groundwater modeling, along with UWMB and its cooperators for the surface watershed modeling and the USGSTowson, Maryland for database and application support. Each participant would likely needs a minimum of $100K per year of extramural support. Model verification through new data collection would require an additional investment, e.g., natural isotope characterization with NRMRLCincinnati. This project will be funded by NRMRL.

2.14 Watershed Ecosystem Model

This objective of this project is to develop integrated knowledge and new tools to enhance predictive understanding of watershed ecosystems including processes and mechanisms that govern interconnected dynamics of water, nutrients, toxins, and biotic components to achieve sustainable ecosystem management at the watershed scale.

The three specific research questions are: (1) What are the quantitative, spatially explicit and dynamic linkages between land use and terrestrial and aquatic ecosystem structure and function? (2) What are the scale of quantitative effects of various combinations of natural and anthropogenic stressors on watershed ecosystems? and (3) What are effective ways to measure changes in landscape including both marketed and non-marketed components and how effective are alternative mitigation approaches, management strategies, and policy options to increasing this value? The proposed research is to: (1) integrate ongoing and new scientific studies over a range of scales from small microcosms to the Patuxent and Choptank river watersheds in Maryland and (2) hold workshops involving the full range of scientific, government and citizen stakeholder groups to communicate results and refine and adapt the research agenda. This project is funded through ORD's NCERQA Grant Program.

2.15 WWF Information Repository

The objective of this project is to provide information to the general public by the establishment and maintenance of an Internet World Wide Web (WWW) site. This site will consist of three major sections: a repository of relevant reports and documents online (including a database of planned or ongoing research projects), WWF characterization data, and WWF treatment control technologies data. A home page for NRMRL-Edison will be developed. The repository will contain titles, abstracts and full text of relevant EPA documents and reports. WWF characterization data collected during the 1970's and entered into EPA’s STORET database willbe converted into a format suitable for searching, viewing, and retrieving through the WWW. Some have expressed concern that the quality of the early STORET data may be poor; EPA has screened it in the past and will continue to do so to assure that it is the best data possible. More recent WWF characterization data will also be included. Process descriptions of WWF treatment and control technologies, cost and efficiency data, and an interactive (online form) for answering frequently asked questions about the technology performance and cost will be included. Information regarding the process descriptions, cost and performance data shall be collected by a number of sources including existing EPA documents, vendor information, published literature, online sources, vendors and municipalities. We will review the USGS WWW site for Texas as a model for how to develop a site to include all the kinds of data and information being proposed, including fundamental "raw" water quality/quantity data, such as NPDES sampling. This project will be funded by NRMRL.

2.16 Sediment Impacts and Control

Three separate sediment issues will be investigated under this Plan: (1) contaminated sediment; (2) erosion, scouring, and sedimentation within the watershed unrelated to contamination; and (3) inclusion of sediment and predeposited sediment in the watershed management strategy and models.

Sediment migration is a serious consideration at the watershed scale. Accumulating and depleting sediment can destroy habitat. Stream bank erosion and bottom scouring reduce sinuosity, ripplepool series, etc. that can shorten residence time, increase water temperature, decrease dissolved oxygen, and otherwise reduce the assimilative capacity of the receiving waters. Sediment control in channels, marinas, piers, and ports resulting from bank erosion, bottom scouring, and land surface erosion is expensive. The problems are amplified when the sediment is contaminated. Research efforts will examine predictive tools and control and reduction practices (BMPs).

Sediment can act as a sink for contaminants entering the water. EPA's Office of Wetlands, Oceans, and Watersheds (OWOW) conducted a national survey that identified areas representing huge volumes of contaminated sediment. All WWFs potentially contribute to contaminated sediment. We anticipate most research effort will emphasize natural attenuation and containment as outlined in EPA’s Contaminated Sediment Management Strategy (EPA, 1994c). The past EPA WWF erosion-sedimentation subprogram will also be reviewed as a basis for this effort. One peer review commenter questioned the value of tracking sediment migration. He indicated: "We know it's a problem, so let's spend our resources developing better ways to keep it from getting into our waterways, and on ways to remove the sediment if it is a detriment to the ambient ecosystem". We will consider this as we develop this project.

This project will be funded by NRMRL. We will tie the WWF research on contaminated sediment directly to the contaminated sediment research plan. We will complete this link when that document is completed.

Research Area 3 - Toxic Substances Impacts and Control

Research Question

How can we effectively prevent and reduce toxic pollutant discharges to receiving waters of the urban watershed?

Research Need

Develop and evaluate methods for characterization of toxic pollutants in the urban watershed during storm events.

Research Projects

3.1. Toxics’ Characterization/Treatment

Earlier phases of this project: (1) characterized toxic substances in stormwater and CSO, (2) demonstrated that stormwater runoff from critical-source areas (e.g., parking lots, storage areas, and especially vehicular-service stations) contribute most of the toxic pollutants to stormwater, (3) conducted bench-scale stormwater toxicants treatability studies, (4) produced a users guide for the investigation of inappropriate non-stormwater connections into storm-drainage systems, and (5) developed a draft user's guide for the assessment of WWF receiving water impacts, and (6) a report comparing the performance of various storm-inlet devices. The major focus of the current phase is to better understand how stormwater toxicants can be controlled upstream at these critical-source areas or “hot spots” prior to entering the WWF-drainage system with the use of a special upstream treatment device, the multichambered treatment train (MCTT). A pilot-scale MCTT has been successfully demonstrated. Two full-scale demonstrations have been installed in Minaqua and Milwaukee, Wisconsin and a third is proposed. These facilities will continue to be evaluated during the current phase. In addition, a pilot-scale study for the optimization of media for removal of toxic substances is being conducted and supported by the U.S. Department of Agriculture, Forest Service’s Forest Products Laboratory in Madison, Wisconsin (Project “Natural Fiber Filtration”). This project is funded by NRMRL.

3.2. Toxics’ Testing/Assessment

This project will develop a wet-weather toxics assessment protocol which integrates existing, standardized impact assessment and analysis procedures with time-scale specific analyses to support the assessment of both short-term and long-term changes in receiving-water system condition or quality. For the typical wet-weather event or discharge the emphasis will be placed on criteria that meet wet-weather discharge event characteristics, not organism based procedures. In this wet-weather assessment protocol, time-scale considerations are the basis for the selection of appropriate assessment procedures. Further effect assessment focuses on measures of direct toxicity because toxicity is produced by both the presence of a contaminant (concentration) and the time-scale (duration) of the exposure. This concentration/duration of exposure relationship is the foundation for the development of procedures for any toxicity analysis, and is particularly important when considering time-scale toxicity/receiving-system impact assessment procedures.

Because time-scale toxicity/receiving-system effect analysis is at the core of wet-weather impact assessment, the proposed protocol is built around toxicity-based receiving-system assessment procedures. The first step includes a review of existing toxicity testing procedures to identify proven and/or standard methods applicable to wet-weather analyses. In standardmethods, such as whole effluent toxicity (WET) testing procedures, the time-scale established in the procedure is based on the time required to produce a specific response, (e.g., LC_{50} or EC_{50}) in the species selected for testing. This protocol is currently being tested and refined as part of a WERF sponsored research project. Furthermore, the protocol will also be applied at the King County, Washington study being conducted on the Duwamish River estuary and Elliott Bay.

This project will provide the information necessary to use "equivalent" toxicity tests to preclude exceedances of State numeric and narrative water quality criteria so that we can move forward with the application of the WET program to WWFs. Validation studies will be considered. The use of approved methods are paramount for acceptability in the application of State water quality criteria. Additionally, the project should use freshwater toxicity test protocols and not the West Coast marine toxicity testing species. If the marine species are used the information will apply only to a limited number of facilities; most WWF discharges are to freshwater streams. This project will also consider the following: (1) determine impact of toxic pollutants on stream biota during low flow periods, (2) determine toxicity of WWF using in-situ long-term mortality testing, (3) determine if one type of pollutant is more responsible for observed toxic effects than the other pollutants, (4) determine the effect of WWF on fish behavior using in-situ testing, (5) determine the quantity of contaminated sediment that must be present in an urban stream to make long-term exposures to low flow fatal to fish, and (6) determine which particle sizes contain most of the toxic pollutants. This project will be funded by NRMRL.

Research Need

Develop and demonstrate methodologies for the most cost-effective pollution prevention strategies for controlling WWF toxicants from their sources.

Research Projects

3.3. Toxics’ Pollution Prevention

The goal of this project is to determine the most effective pollution-prevention strategies for watershed protection. Research areas identified over a decade ago in EPA's Nationwide Urban Runoff Program (NURP) (EPA, 1983) study include the prevalence of high exceedances of copper, lead and zinc in urban receiving waters. A national estimate of potential pollutants emanating from construction material, surface coatings, and man-deployed chemicals and their toxicity will be analyzed for potential risk. Pollutants will be categorized using the following general source areas: residential, construction, industrial, agricultural, municipal, and commercial. Within these general source areas, critical-source areas (highly toxic runoff sources) will be identitfied. In addition, careless storage and drainage practices in the upstream areas of the watershed will be identified. A risk analysis for pollution-prevention techniques (product substitution; controlled use of chemicals; and improved handling, drainage, and storage practices) will be conducted. Further, an analysis of the fate, transport and environmental effect of copper from automobile brake pads as well as automobile accessories (highways, gasoline stations, automotive businesses) will be addressed. Work on characterization and source control was done for the City of Bellevue in 1995. Their major recommendations were: (1) a watershed approach should be used, rather than a land use-based approach, for monitoring and characterizing stormwater discharges and water quality, (2) emphasis should be placed on source control ratherthan "more" water quality monitoring, and (3) water quality standards should be revised to reflect the episodic nature of stormwater discharges.

This project will be funded by NRMRL.

Research Need

Develop and demonstrate new, low-cost, high-rate control/treatment technologies for removing toxic pollutants from WWF and evaluate their effectiveness relative to meeting water-quality goals.

Research Projects

3.1. Toxics’ Characterization/Treatment This project is described in detail above.

3.4. Natural-Fiber Filtration

The U.S. Forest Products Laboratory (FPL) and the WWF Program will enter into an interagency agreement for evaluation of WWF-filtration media comprised of natural agro and wood fibers. The filtering media has and is being studied by the FPL. Research for application of the filtering media to WWF treatment will be conducted by the University of Alabama (UAB) under a separate project. This research will investigate the adsorption, desorption, and ion-exchange capabilities of wood- and agro-fibers. Based on stormwater pollutant removals, the FPL and UAB will attempt to optimize the design and fabrication of the filtering fabric. The goal of the project is the development of a replaceable and marketable filtration device with an inexpensive, renewable, and disposable filtering material capable of removing dissolved toxic organics and metals. Sand filters are a proven technology for the removal of particles from WWF; however, they are ineffective at removing dissolved or colloidal pollutants. Activated carbon, which can remove dissolved pollutants, is expensive and accordingly an alternative medium is much needed. This project will be funded by NRMRL in support of funding by others.

3.5 Toxics' Risk Assessment

This project will analyze WWF toxicants in much greater detail than what has been done so far. Without toxic substances in storm runoff assessment and control, our various hazardous substances cleanup and control programs (under CERCLA/SARA, RCRA, TSCA, etc.) may be done in vain. Additional investigation of the significance of concentrations and quantities of toxic pollutants with regard to their health effects or potential health effects and ecosystem effects is required. A need exists to evaluate the removal capacity of conventional and alternative treatment technologies and BMPs for these toxics and to compare their effectiveness with estimated removal needs to meet water quality goals. From this comparison further advanced treatment and control for toxic substances will need to be developed. This project will be jointly funded by NRMRL and NERL/NHEERL.

Research Area 4 - Control Technologies

Research Question

Is there a better way to design and operate sewerage systems given the concern for urban WWF pollution? Are there emerging technologies that can be used for treating WWF at a reasonable cost?

Research Need

Develop and demonstrate cost-effective land-management strategies that would rely on pollution prevention and low-structural approaches to reduce the load of pollutants and high flows entering the drainage system.

Research Projects

4.1. Rouge River Restoration

This is a national project to demonstrate effective solutions to water quality problems facing an urban watershed highly impacted by WWFs and develop potential solutions and implement projects which lead to the restoration of water quality in the Rouge River, Wayne County, Michigan. The project is developing certain tools for watershed analysis and planning. Using an environmental GIS, hydrological and water quality models, and a watershed management decision-support system developed through this project, the Rouge River Watershed will be able to be managed in a comprehensive and rational manner. These tools will be formulated for use on the Rouge River, but will be designed to allow transferability to urban watersheds throughout the country. Although river characteristics, rainfall quantities, land use, sewer-drainage system configurations, and other factors will be different, the methodology used within the Rouge Project, and the analysis procedures and systems which are being developed, will be adaptable for use by other planners.

A large body of data has been collected in connection with this project. Data sets include: stream water quality profiles in wet and dry weather; synoptic sets of source and in-stream water quality data in both the combined- and separated-sewered areas of the watershed; and sediment quality data. These data are available on CD ROM, and can be viewed under a Windows Application called Data View. In addition, a number of QA/QC manuals have been developed to cover the sampling program, including field-sampling techniques, chain of custody, laboratory analysis, and data reporting and analysis.

The project is evaluating various WWF control prototypes, including eleven different designs of CSO detention basins for capture and treatment efficiency and a number of different stormwater runoff quality control BMPs including nine structural BMPs, five wetlands, and four developed watersheds in which source controls are being intensively applied. This is a Congressionally mandated project.

4.2 BMP Manual

The OWM has requested that the WWF Program write a guidance manual on the use of stormwater control or BMPs to minimize cross-media transfer of contaminants during WWF conditions. Many BMPs have been installed without the benefit of past performance data; therefore a timely review of the performance and longevity of the most appropriate practices should be made to assist the user community. This guide will evaluate the relationship of rainfall rates, imperviousness, and influent pollutant concentration to BMP performance, especially theremoval of metals and toxic organics. It will also assess the effect of programmatic BMP (e.g., education for pesticide usage and waste-oil recycling), maintenance and safety considerations, applicable federal regulations, and computer modeling. Simple controls associated with development options including the effects of roof drain disconnections, pavement drainage disconnections, and grass filters will be addressed. National cost estimates will be considered, including data from "Nationwide Costs to Implement

BMPs" (American Public Works Association, 1992). This report identified possible capital costs of up to $407 billion and annual operations/maintenance costs of $542 billion necessary to meet water quality standards for stormwater discharges. This project will be funded by NRMRL in support of funding by OW.

4.3 Industrial Runoff Control

Industrial stormwater runoff permits are required for various industries. This project will demonstrate various low-structurally (e.g., better housekeeping practices) and structurally-intensive control techniques at a large industrial site. The project will be conducted with the cooperation of an industry. This project will be funded by NRMRL.

4.4. Management for Small Communities

Phase II of the OWM stormwater permitting program will require small communities, i.e., with populations less than 100,000, to be permitted for stormwater discharges. This project will produce a manual for stormwater management and pollution control for these small communities. This project will be funded by NRMRL.

4.5. Roadway/Airport Deicing

This project will update two existing EPA documents on deicing salt pollution control for storage/handling and application practices (“Manual for Deicing Chemical Storage and Handling” (EPA670/274033) and “Manual for Deicing Chemicals: Application Practices” (EPA670/274045)). Roadway deicing is a major environmental problem causing pollution of drinking water and automobile and highway damage costing the nation approximately ten billion dollars a year. This project will be funded by NRMRL.

4.6. BMP Design/Effectiveness

This project involves the collection of all available existing information pertaining to the effectiveness of structural and non-structural stormwater management BMPs and pollution prevention measures. ASCE and WERF will cooperate to compile this information into an accessible database that can be used by all stakeholders in the stormwater field. ASCE will identify areas of information that are missing or incomplete that need to be addressed by future research areas. WERF is conducting a similar effort to develop WWF treatability impact evaluation protocols and will cooperate in data/information compilation with ASCE. A specific evaluation of source vs treatment controls will be conducted which addresses under what circumstances one or the other should be chosen by use of cost/benefit information. This project is funded by OW under its 104b3 Cooperative Agreement Program.

4.7. Urban BMP Effectiveness

The purpose of this project is to define four different geographic areas and four different types of watersheds and relate level of watershed imperviousness to receiving-water impairment. Thisproject is funded by OW under its 104b3 Cooperative Agreement.

4.8. Runoff Control Using Compost

This project will evaluate using compost as a soil amendment to: increase stormwater infiltration, reduce the quantity and/or intensity of surface and subsurface stormwater runoff, and reduce transport of dissolved or suspended phosphorous (P) from stormwater runoff by soil sorption. Research has demonstrated compost's effectiveness in improving the soil's physical properties of porosity and macropore continuity. Compost's chemical properties are also valuable for their potential to sorb harmful metals and nutrients. It is a low cost and low maintenance way of reducing polluted stormwater runoff from public and private turf areas constructed on soils with low permeability. It reduces storm-flow pollution while also reducing solid waste by recycling composted material. A bench-scale study, examining maximum sorption rates for P in glacial till and compost-amended glacial till soils, will complement the field examination. This project will be funded by NRMRL.

4.9 Riparian Forest Management

The objective of this project is to develop a model urban forest management plan for NPS pollution control within the Manahawkin Creek Watershed in New Jersey. A major component of the plan would be recommendations, based on established USDA Forestry Services principles or management of the riparian forests within the watershed to enhance the ability of these riparian forests to remove sediment and other pollutants from the urban stormwater runoff. Manifestations of this project would include a workable urban forest management plan which would be implementable by Stafford Township as part of its overall stormwater management plan. In addition, the plan would be structured so that it could also be used as a model by other communities to aid them in establishing their own urban forest management plans for NPS pollution control. This project will be funded by NRMRL.

Research Need

Develop and demonstrate advanced collection system design alternatives to reduce WWF overflows, optimizing in-sewer storage and flow routing systems in conjunction with storage basins and WWTPs and evaluate whether new sewerage systems should be separate or combined.

Research Projects

4.1. Rouge River Restoration

This project described in detail above also addresses this research need.

4.10. CSO Measures of Success

Under this project, the Association of Metropolitan Sewerage Agencies (AMSA) is working with CSO stakeholders (EPA, States, communities with combined sewer systems, and environmental groups) to identify programmatic and environmental measures that can be used by communities to determine the effectiveness of their CSO control programs in achieving the objectives of the national CSO control policy. The project encompasses four tasks, involving a multi-disciplinary workgroup and constituency focus groups to identify lists of indicators that stakeholders can use to effectively measure the success of CSO control programs. Indicators include: (1)programmatic, (2) instream, (3) end-of-pipe controls, and (4) ecological and use attainability. This project is funded by OW under its 104b3 Cooperative Agreement Program.

4.11. Flow Balance Method

This pilot-scale demonstration is supported by a $1,000,000 EPA OW Marine Grant to the New York City Department of Environmental Protection (NYCDEP). NYCDEP’s share is estimated at $1,000,000. The flow balancing method (FBM) is an in-receiving water storage system comprised of pontoons and submerged, flexible plastic sheeting that captures WWF for pumpback to a treatment facility. Storage is a necessary part of any CSO control and treatment approach. FBM construction materials cost less than conventional basin storage. Most of the expense in conventional storage is devoted to concrete and steel for structural support whereas the FBM relies on passive-water pressure of the receiving water for structural support. The NYC FBM project is the only saltwater system in existence. Captured CSO floats on top of the seawater due to the difference in density. The first phase of this project was supported by a $500,000 ORD cooperative agreement that resulted in various conference presentations and papers and importantly, two peer-reviewed journal articles. The current phase of the project is an expansion of the original pilot-scale project initiated in 1987 and will evaluate CSO capture effectiveness for WWTP pumpback. The earlier phase of the project demonstrated that effective CSO control is achieved by the FBM and its principals of operation and sea-worthiness. The FBM requires further evaluation to gain wider acceptance. This project is funded by OW .

4.12. Storm Inlet Infiltration Device

Storm inlet device may be divided into two broad categories: devices that use screens to filter stormwater prior to discharging into a sewer (project 3.1 (6) Toxics' Characterization/Treatment) and devices that treat the stormwater prior to subsurface infiltration. This project will evaluate storm-inlet-infiltration devices designed to be inserted into street stormwater inlets to transform them into a treatment device prior to subsurface infiltration discharge. Infiltration is being pushed in Europe and Japan to minimize the amount of polluted runoff that must be dealt with, enhance groundwater/drinking water supplies and enhance base flow. These have been applied in Maryland (where they failed because the installations were not done properly) and in central Florida (where everything works because of the sugar-sand topsoil. Replaceable filtering medium consists of gravel, sand, and/or carbon to treat stormwater prior to soil infiltration. The first part of this study will be a desktop evaluation using data available from previous investigations from installed devices if available. This data will be compared with the sorption capacity of the filtering media. Based on the results of the desktop evaluation, an actual field evaluation of various configurations will be performed. Due consideration will be given to all previous work in this area. This project will be funded by NRMRL.

4.13. Stormceptor's Storm Inlet Device

This project will be a field evaluation of a full-scale, storm inlet device from the Stormceptor Corporation. Performance of this device will be compared to the performance of an optimized catchbasin that was evaluated by EPA in 1983. Another possibility is a side-by-side field testing of the Stormceptor device and other storm inlet devices, such as an optimized catchbasin infiltration (see 4.12 above, SAGES), or Continuous Deflective Separation (CDS). This project will be funded by NRMRL in support of funding by others.

4.14. CDS Stormwater Treatment

This project will be a full-scale evaluation of a stormwater treatment device called Continuous Deflective Separation (CDS) system that was developed by Pollutec Ltd., an Australian firm. The device is a pollutant trap system for removal and retaining of particulate matter, litter and debris with a hydraulic flow feature that protects the separation screen from clogging. The CDS consists of a circular solid-liquid separation chamber where WWF is allowed to pass through a circular screen/deflection plate, which removes suspended solids. The innovative deflection mechanism creates a circular continuous flow pattern over the face of the separation plate and, thus, protects it from accumulating debris and from clogging. The CDS system can be incorporated into new pipe systems or retrofitted into existing ones as well. There is a potential to implement the CDS evaluation at the New York Rockland County Sewer District (RCSD) WWTP under an extension of the existing Cooperative Agreement between the OWM and the RCSD. Currently, the RCSD is conducting an evaluation of high-energy mixing and UV disinfection technologies at their WWTP with $500 K in grant funding from the New York State Energy and Development Authority (NYSERDA). The addition of the CSD evaluation at the same plant is being discussed. Another possibility is a side-by-side field testing of the CDS device and other storm inlet devices, such as an optimized catchbasin, SAGES, or Stormceptor device. This project is funded by OW under its 104b3 Cooperative Agreement Program.

4.15. Cross Connection Identification

The University of New Orleans Urban Waste Management Research Center was awarded an EPA grant to demonstrate the WWF Program's interim "User's Guide for the Investigation of Inappropriate Pollutant Entries into Storm Drainage Systems" (EPA/600/R-92/238). An actual municipal application will be conducted in New Orleans to assess the interim User's Guide's usefulness for identifying unauthorized and illicit residential sanitary sewer and industrial wastewater connections to the storm-drainage system. Where necessary, modifications will be made and a final updated user's guide will be published. A training manual and seminars will also be provided. This project is funded under the Regional 104b3 Cooperative Agreement Program.

4.16. Storage Facilities Design

This project will provide a design manual for multipurpose storage-sedimentation facilities integrating pollution, erosion, and flood control. The manual will provide engineering guidelines and information in support of watershed management at the local level, which is part of the ‘Scientific and Technical Advice’ component of the ORD Strategic Plan. The scope of this project includes: (1) compiling existing data on the effectiveness of CSO, stormwater, and SSO storage, sedimentation, and treatment methods; (2) verifying recommended storage/treatment approaches through computer modeling; (3) finalizing a 1981 EPA report currently in the draft final form entitled <u>Storage/Sedimentation Facilities for Control of Storm and Combined Sewer Overflows Design Manual</u>; and (4) developing a second volume to this document as a more detailed engineering manual for storage/treatment optimization. Low-flow augmentation with stored WWFs will be examined. This project will be funded by NRMRL.

4.17. Real-Time Control by Radar

This project will demonstrate application of a radar-based rainfall monitoring system, by the trade name of CALAMAR, to maximize the in-line CSO storage capacity. CALAMAR, developed bya French firm RHEA, S.A., is a patented system of hardware and software, which processes and calibrates data from Doppler weather radar, and produces accurate measurements of rainfall intensity and accumulation at any point within sixty miles of radar location . When installed in the “real-time” mode, CALAMAR will also provide short term forecasts of rainfall intensity. In this project, CALAMAR will be used in the real-time mode to provide the sewerage operators with advanced warning of stormwater accumulation in different catchments at a given time. This advanced information will allow the operators to store and route the flow in the most efficient manner. Optimization of the CSO in-line storage capacity is a cost-effective approach because it minimizes the construction of new storage facilities. It also prevents releases of untreated CSO during a rain event. This project is being considered for an FY97 start. This project will be funded by NRMRL in support of funding by others.

Research Need

Develop and demonstrate high-rate and high-efficiency treatment technologies suitable for retrofitting existing WWTPs as well as for new installations.

Research Projects

4.1. Rouge River Restoration

This project described in detail above also addresses this research need.

4.18. CSO Vortex Controls

The NYCDEP is conducting a side-by-side, full-scale demonstration of three different types of vortex units primarily for floatables removal and secondarily for other pollutant removals. This facility will be the first in the world to test three types of vortex devices side-by-side. The facility will contain three 43-foot diameter vortex units of varying depths. The three units include the EPA swirl, the German Fluidsep®, and the United Kingdom Storm King®. These units have been tested individually in other locations but have never comprehensively been tested side-by-side. The results obtained from this facility will have potential application to over 400 outfalls in New York City.

The facility is being constructed completely underground below Corona Avenue adjacent to the Flushing Meadow-Corona Park in Queens, NYC. The facility will occupy a space of 80 ft by 394 ft and will include a control room and several sampling stations throughout the facility. Channel configurations and sampling equipment have been designed to provide equal splitting of CSO quantity and quality to each of the three units.

The sampling and analysis program includes: floatables (sampled with small aperture mechanical screens at strategic points throughout the facility), suspended solids, BOD, nutrients, and bacteria (sampled from multi-port continuous flow stream sampling devices connected to automated samplers). The WWF Program will participate (under the authority of the WERF as a member of the Wet Weather Advisory Panel) in a joint-venture evaluation of this project. The NYCDEP cost for this project is estimated to be $40,000,000. This is a WERF Category 1 project which will be funded by NRMRL in support of funding by others.

4.19. High-Rate Sedimentation

This project will demonstrate and evaluate high-rate sedimentation processes, e.g., ActiFlow, Microsep, Densadeg and lamellae plate settling. The ActiFlow and Microsep processes consist of chemical coagulation with microcarrier media (e.g., microsand) as a nucleus followed by flocculation and settling. The innovative feature of this process is that the coagulant nucleus, microsand, is recycled for reuse in the flocculation basin. The microsand settles out with the sludge and is removed by a hydro-cyclone for reuse. The microsand acts as a catalyst improving flocculent settling. The ActiFlow process also uses the lamellae settling principles and the Dengadek process recycles its chemical coagulants for reuse. Studies of these processes in North America and Europe have demonstrated its suitability as an effective WWF control alternative. If funds or leveraged funds were made available to the WWF Program, a bench-, pilot-, and full-scale WWF treatment plant could be constructed and evaluated, and/or the system could be retrofitted in an existing WWTP. Benefits of these processes include: high-rate settling, reduced cost for coagulant aid or coagulant (reuse of microsand or coagulant with minimal makeup); amenability for retrofitting to improve primary treatment (which is in accordance with “Combined Sewer Overflow - Guidance for Nine Minimum Controls” part of the EPA’s “National CSO Control Policy”); and low cost high-rate treatment requiring less land. As part of this project, we will evaluate whether a national treatability study could be carried out, including looking at pollutant speciation, fractions associated with settleable particulates, native soil type effects, etc. This project will be funded by NRMRL in support of funding by others.

4.20. Magnetic Separation

This is a proposed treatment technology for WWF that has been used successfully for a number of years for industrial wastewater treatment. A high degree of treatment is possible with this process. In its simplest form, the high-gradient magnetic separation (HGMS) consists of a canister packed with a fibrous ferromagnetic material that is magnetized by a strong external magnetic field (coils surround the canister). The water to be treated is passed through the canister and the fibrous ferromagnetic matrix causes only a small hydraulic resistance because it occupies less than 5% of the canister volume.

Upstream of the canister the water is prepared by binding finely divided magnetic seed particles, e.g., magnetic iron oxide (magnetite) to the nonmagnetic contaminants. Binding the magnetic seed is accomplished in two ways: adsorption of the contaminant to the magnetic seed and chemical coagulation (alum). The magnetic particles are trapped on the edges of the magnetized fibers in the canister as the water passes through. When the matrix has become loaded with magnetic particles, they are easily washed off by turning off the magnetic field and backflushing. Particles ranging in size from soluble through settleable (>0.001æm) may be removed with this process. Eventually high levels of treatment including toxicant removal will be required for WWF in various locations and HGMS is a process that can meet this requirement. This project will be funded by NRMRL in support of funding by others. A municipal partner will be sought for project leveraging.

4.21. WWF Design Protocols

This project will develop analytical protocols for producing pertinent WWF pollution abatement facility design data by: (1) particle settling velocity and size distribution along with availablepollutant analyses, (2) partitioning the floatable, particulate and dissolved fractions of pollutants, (3) the statistical analysis of historical rainfall and WWTP data to alleviate dependancy on expensive and time consuming WWF monitoring, and (4) determining maximum particle sizes and other particle characteristics allowable for effective disinfection treatment. The EPA “National CSO Control Policy” requires primary treatment followed by disinfection (when necessary); however this requirement is being made without characterizing the particle size limitations for effective disinfection. Without this knowledge specific primary treatment/process and design requirements cannot be made. Furthermore, without adequate WWF suspended and dissolved solids partitioning and particle size/settling velocity distribution analyses, primary treatment design cannot be made properly. Initial phases of this project can be developed through desktop analysis; however, the experimental stages will require the development of either an intramural laboratory or performed under a cooperative agreement. This project will be funded by NRMRL and supported by a Cooperative Research and Development Agreement (CRADA) to John Meunier, Inc..

4.22. Retrofitting Control Facilities

This project will investigate the retrofitting of existing sewerage systems to handle additional WWF (SSO, stormwater and CSO). Two basic techniques are: 1) increasing the hydraulic loadings at the control facilities, and 2) increasing the amount of storage in the conveyance system. Techniques to be investigated include: 1) converting existing “dry-ponds” (ponds that drain and go dry between storm events) to “wet-ponds” for separate stormwater systems to enable treatment through sedimentation, and 2) converting or retrofitting primary settling tanks to dissolved air flotation and lamellae and/or microsand-enhanced plate or tube settling. Retrofitting processes will better enable communities to meet EPA’s CSO National Control Policy. This project will be funded by NRMRL.

4.23. CSO Concepts for Stormwater

This project will produce methodologies for applying CSO control and treatment methods to improve separate stormwater systems. The methodologies will delve into applicable storage, treatment and flow-control techniques currently practiced in CSO systems. As more separately-sewered stormwater systems require increased permitting, treatment and control methods for discharges need to be assessed. CSO systems have already been developed to address the storage concepts and high-rate intermittent treatment necessary to remove pollutants from storm flow. The goal will be to maximize the treatment capacity of the existing systems. This project will be funded by NRMRL.

4.24. SSO Corrective Action

This project will develop methodologies for control practices for SSO. Corrective actions by storage, treatment and sewer rehabilitation will be investigated. The work will also include determining the risks and impacts to groundwater from sewer exfiltration. In particular, the project will investigate: (1) impacts of peak flows and RII on SSO for existing sewers, (2) effective monitoring and control measures and their costs, and (3) new design and construction techniques for preventing SSOs in new sewers. The limits to infiltration control would also be investigated (based on associated parameters, e.g., risks associated with different soils, construction methods, and water level). The study and manual follows the research needs andrecommendations from the recent National Conference on Sanitary Sewer Overflow held in Washington DC in April 1995 and published in “Final Report: Sanitary Sewer Overflow Workshop” (August 1995). A paper addressing SSO issues will be presented at the “7th International Conference on Urban Storm Drainage” in Hanover, Germany. This project will be funded by NRMRL.

4.25. Impacts/Effectiveness Protocols

This effort will produce protocols that can be used to characterize and evaluate the effectiveness of WWF control and treatment technologies in removing pollutants and the resultant impact on water quality. States and municipalities can use the protocol to assess the performance of the implemented WWF control measures and to determine whether the performance meets the expectations of the original design. This project is funded by OW under its 104b3 Cooperative Agreement Program.

4.26. Vortex/Disinfection Treatment

This project is an advanced research demonstration project, funded via Congressional budget line item, that will demonstrate on a full scale, the applicability of new, lower cost, more environmentally acceptable processes for the treatment of CSOs, using six, 32-foot diameter vortex separators, two of which can operate as primary or secondary units (secondary units receive flow from the underflow of the primary units thus concentrating the residuals that are sent to the sewer system), high-rate filtration, UV disinfection, appurtenant flow metering, flow control, and three with air dissolving tubes and float removal mechanisms. The project is being conducted at two sites in Columbus, Georgia. Specific goals of this project include: providing comparative process results for various treatment technologies that can be used by other CSO cities in determining what level of control might be necessary for meeting their site-specific water quality requirements; providing design criteria and capital and O&M costs for use by other CSO cities in determining cost-effectiveness answers to their own site-specific constraints; determining split-flow capabilities of process combinations for matching treatment level with the variable nature of wet-weather hydraulics and pollution, thereby reducing control costs of meeting water quality objectives; determining appropriate hydraulic controls and operations necessary for remote technology siting, thus reducing overall CSO control costs and more effectively solving the pollution problem at its source; determining cost-effective methods for remotely concentrating and batch removal of residuals to minimize hydraulic load impacts on the wastewater treatment plant, thereby providing more capacity for handling WWFs, such as infiltration/inflow, and preventing SSOs; determining annual statistical hydraulic and pollutant loading and possible relationships with individual time related loadings and integration with process performance that can be applied to comply with the 1994 EPA CSO Control Policy.

Discrete and composite sampling will be performed at the influent, effluent and sidestreams for each unit process. Discrete sampling will be performed at small enough intervals to establish flush conditions and process performance during those conditions. Analyses will be conducted for conventional and specific priority pollutants, bacteria, oil and grease, particle characteristics and toxicity. This is a Congressionally mandated project.

4.27. Crossflow Plate Settlers

One of the nine minimum controls of the EPA’s National CSO Control Policy is to force more CSO through the primary settling tanks for treatment prior to release in the receiving water. Efficiency of primary treatment and overflowrates can be increased by retrofitting with high-rate treatment methods. This project will demonstrate CSO treatment using an existing WWTP primary settling tanks retrofitted with crossflow plate settlers. The successful application of plate settling technology will provide a way to decrease cost of CSO control and will decrease the need for newly constructed storage and treatment facilities and additional land requirements. This project will be funded under EPA's Environmental Technology Initiative/Environmental Technology Verification (ETI/ETV) program.

4.28. High-Rate Disinfection This project will demonstrate and compare high-rate disinfection technologies applied to CSO after primary clarification, part of the EPA’s National CSO Control Policy. Technologies to be potentially demonstrated include: static and mechanical/dynamic mixing; sequential addition of sodium hypochlorite and chlorine dioxide; ozonation; chlorine dioxide alone; and UV light irradiation. These high-rate processes will be compared to conventional sodium hypochlorite disinfection. The characteristics of intense storm-generated flows necessitate the adoption of cost-effective and high-rate disinfection facilities adaptable to intermittent use and varying dosage requirements. This project may include an evaluation of the potential for accidents or mishaps, such as from the explosive nature of ozone or the potential for exposure to the general public with the use of chlorine compounds. This project will be funded by NRMRL in support of funding by others.

4.29. Demonstration of Biofilters This project will demonstrate biofilters as a multi-purpose treatment method. The use of biofilters will enable a treatment plant to handle two to three times DWF as opposed to the conventional design of one and a half times DWF. Biofilters achieve better removals than that required by the EPA's National CSO Control Policy. The filters will also enable the treatment plants to remove additional BOD and ammonia which will result in higher dissolved oxygen levels in the receiving-water bodies. This project will be funded by NRMRL in support of funding by others.

4.30. High-Rate Ozonation

Conventional disinfection technologies cannot be readily applied to CSOs. The difficulty stems from the fact that CSOs occur randomly, the flowrates depend on the intensity and duration of the storm, the water quality characteristics of each CSO event vary and are highly dependent on local and seasonal conditions, and the flow is of intermittent duration. Consequently, the effective disinfection process will have to provide the desired microbial deactivation very rapidly under the specific CSO conditions and carry very small amounts of or no residual into the receiving-water stream or water body. Among the available proven disinfection technologies, ozonation is known to have the highest oxidizing power, and due to its high reactivity with water, does not carry residual. It is therefore proposed that ozonation be evaluated as an alternative disinfection process for CSO.

A one million gallon/day pilot project is proposed that will provide for the design, construction, operation, and maintenance of a full-scale ozone CSO disinfection system in Fresh Creek with the goal of reducing microbial pollution to Jamaica Bay, New York. This project will be funded by NRMRL in support of funding by others.

4.31. Triple Purpose Storage

This project will demonstrate the successful CSO storage concept as applied to separate storm drainage, sanitary sewer, and combined sewer system discharges. The conventional CSO storage concept uses the existing WWTP for treatment. A site will be sought that can demonstrate multipurpose storage for an urban system that contains: (1)

stormwater and inappropriate non-stormwater discharges from storm-drainage, (2) CSO, and (3) DWF from combined or sanitary sewers. This storage system should provide a higher degree of treatment than current stormwater pollution control which usually employs retention/detention without downstream treatment and soil infiltration practices that may lead to soil and groundwater contamination. Importantly, it uses one storage facility for multipurpose controls and recognizes that increasing in-stream flows during critical periods is an important contemporary management tool. Storage is considered a necessary control alternative because storm flow is intermittent and highly variable in pollutant concentration and flowrate. Auxiliary storage functions may include sedimentation treatment, flood protection, flow attenuation, DWF capture and attenuation, sewer relief, and low-flow augmentation. The WWF Program would identify a municipal partner(s) with adequate existing facilities willing to adopt this storage strategy. This project will be funded by NRMRL in support of funding by others.

Research Need

Demonstrate and evaluate the use of natural and created wetlands for management of WWFs in urban areas, including collection of design and operational data for optimal performance.

Research Projects

4.1. Rouge River Restoration

This project described in detail above also addresses this research need.

4.32. Harlem River Wetlands

Demonstration of technologies for CSO treatment involving: flow balance method in-receiving water storage, inline floatables removal, and constructed wetlands for CSO treatment. This multifaceted project includes restoration of the Spuyten Duyvil area of the Harlem River, such as riverfront upgrade and many other public recreation projects. The WWF Program will collaborate with New York State and NYC to conduct this project. This project will be funded through a Federal Highway Administration grant and NRMRL.

4.33. Storage/Wetlands Treatment

In September 1995, the WWF Program in conjunction with Onondaga County Department of Public Works, N.Y., received a $100,000 Environmental Technology Initiative (ETI) award for a demonstration project in the Harbor Brook watershed. The Onondaga County share will be $5,300,000. The 8,600 acre watershed which drains into Onondaga Lake in Syracuse, N.Y.,contains 1,300 acres of combined and 3,060 acres of separate storm-sewer drainage area, respectively. This project will develop and evaluate an innovative system for a watershed approach to the control of WWF by combining an in-brook TrashTrap™ netting system, an in-lake EquiFlow™ (or Flow-Balance Method [FBM]) storage system, and an existing/constructed wetlands treatment. The TrashTrap™ will remove the larger materials and the floatables in Harbor Brook while the captured WWF will be balanced (equalized) by FBM storage, and then either pumped to the WWTP or directed through the wetlands for treatment. This project will also assess the effectiveness of constructed wetlands at removing pollutants from WWF in northern climates. Results of this watershed approach will be incorporated into the Watershed Management project. This project is funded under EPA's ETI program in support of funding by others.

4.34. Constructed Vegetative Treatment Cells

This project supports the development and implementation of Constructed Vegetative Treatment Cells (CVTC) for CSO remediation. CVTCs require little construction and operating equipment resulting in low capital costs and O&M requirements. In the laboratory, CVTCs have addressed multiple-pollutant problems. CVTCs function as a physical/biological treatment system. CVTCs remove suspended solids and their associated pollutants by settling and biological contaminants through uptake of nutrients by the plants or as a fixed media for attached microorganisms while also behaving as biological aerators. This demonstration will generate monitoring, process control, and O&M data necessary to facilitate widespread implementation of CVTC technology for CSO remediation. This project is funded by the ETI/ETV program in support of funding by others.

4.35. ETV Pilot for WWF Control Systems

In August 1996, resources were provided to the UWMB for an Environmental Technology Verification (ETV) pilot program to verify commercial WWF control systems. The EPA‘s ETV program, initiated in October 1995, is to provide credible environmental technology performance data and cost. Under an ETV pilot program, technologies are evaluated by a disinterested third party under a cooperative agreement with EPA and with some EPA funding. Technology developers are solicited by the evaluating party to provide: (1) their treatment units, (2) operation of systems in the field, and (3) significant financial contribution to the cost of evaluation, including sampling and analytical costs. The technology performance results are distributed widely through an Evaluation Report (hard copy) and a Verification Sheet done by EPA on the Internet. Under the WWF Pilot, the recipient of ETV award, a testing organization, would solicit all interested vendors for evaluations to verify effectiveness of their systems and determine their costs. This would pertain to the WWF Inlet Treatment Devices and to the WWF High-Rate Treatment Technologies as well.

WWF Inlet Treatment Devices. These devices are designed to be placed in an inlet, collect or remove solids, and prevent resuspension of solids during subsequent storms thereby preventing their entry into the treatment plant or the receiving stream. The verification program would answer several key questions that affect the efficacy of these units, such as possible removal efficiencies, maintenance (especially needed frequency of cleaning), and other operationalcharacteristics.

Advanced High-Rate WWF Treatment Technologies. Four general groups of high-rate treatment technologies are being evaluated: sedimentation, micro- and fine-mesh screening, biological, and disinfection processes. All high-rate technologies are compact and capable of high throughput. Since storm flows are significantly greater than dry weather flows, use of high-rate processes requiring less tankage and space is significantly more cost-effective than use of conventional processes.

The major steps in developing this ETV Pilot are: (1) to establish a stakeholder group for the life of the WWF pilot, (2) using the competitive procedure, establish a cooperative agreement (CA) partner who would be the disinterested third party for conducting verification testing, (3) after the CA award, EPA will cooperate closely with the CA partner to implement the multi-year verification program. This project is funded by NRMRL with ETV funds.

4.36 Sewer and Tank Sediment Flushing

The objective of this project is to develop and test innovative, cost-effective methods for flushing sewer sediment and WWF storage tank bottom sludge to prevent pollutants from directly discharging to receiving waters during storm-flow conditions and alleviate expensive and significant maintenance problems, respectively. For effective maintenance of storage tanks, it is necessary to remove settled solids and debris soon after each storm event. Two methods (i.e., tipping flushers and flushing gates) for cleaning accumulated sludge and debris in storage tanks have been widely used in Germany and Switzerland. However, both technologies require moving parts and control instrument systems to operate for creating high velocity/energy flushing waves to sweep the settled sludge to a channel for further treatment and disposal. This project will investigate the feasibility of hydraulic-balanced methods for creating resuspension energy for sewerline and tank cleaning and demonstrate the new innovate methods at field WWTP sites. This will be an NRMRL funded project.

Research Area 5 - Infrastructure Improvement

Research Question

What are the best approaches to rehabilitate existing and construct new sewer systems in urban settings?

Research Need

Develop and demonstrate new technologies that can be used to construct, maintain, and repair new and existing sewer infrastructure at an acceptable cost.

Research Projects

5.1 Infrastructure Rehabilitation

This project will develop a summary of national data on I/I reduction resulting from multiple rehabilitation approaches. Data will be compiled for three categories: mains only, mains andlower laterals, or comprehensive rehabilitation (mains, lower laterals, and private sector service lines). Investigations to quantify types of I/I reduction by peak flow or flow volumes, and efforts to relate I/I to rain-induced infiltration (RII) and groundwater infiltration will be conducted. Other variables will be defined including size and type of repair performed. Cost data will be developed for rehabilitation, including cost per foot of pipe (either based on system-wide length of pipe or based on feet of pipe rehabilitated) or cost per gallon of I/I removed. Cost data will be collected on sewer system replacement activities. Areas to be examined include annual investment in rehabilitation (percent of system value) and expected design life of the sewer system. The cost data will be used to examine whether annual investment matches expected design life. The project will also develop generalized guidance, if possible, on the minimum cost of system rehabilitation for I/I reduction, or the minimum cost per foot of pipe in the system. Future activities in this project will encompass the development of technical guidance on engineering and construction practices for new facilities in an effort to minimize I/I. The guidance will cover pipe and manhole materials, pipe joint design including new flexible water-tight pipe connections for house service laterals, designing laterals to be accessible to TV inspection, and installation techniques. Furthermore, leaks and structural integrity technologies in municipal potable water distribution systems and possibly heat and gas distribution systems will be developed and demonstrated. Since 30% of the cost of water, on a national basis, is due to leaks from the distribution system, such research will fulfill a national need and result in a significant cost savings on a national basis. This project will be funded by OW under its 104b3 Cooperative Agreement Program and NRMRL.

5.2 Sewer Maintenance Effectiveness

The objective of this project is to develop a methodology for use by permittees and permitting agencies to evaluate the adequacy of a sanitary sewer collection system O&M program. The methodology will contain information on how to: (1) establish an effective collection system O&M program to maintain functional and structural integrity, (2) evaluate the adequacy and effectiveness of an existing collection system O&M program, and (3) prevent new connections and reconnections of inflow sources. Supporting documentation for the guidance will be obtained via literature search, telephone discussions, and at least six collection system data/information gathering visits. This project is funded by OW under its 104b3 Cooperative Agreement Program.

5.3 Sewer Maintenance Optimization

The objective of this project is to develop an optimized approach for maintenance of collection systems. This effort will result in a decision-making model which can be used by cities and agencies in evaluating the cost of maintenance (as measured by maintenance frequency) and system performance. Specific objectives are to: (1) evaluate the effectiveness of maintenance and rehabilitation programs by reviewing the inspection activities and their frequency; (2) review how maintenance and rehabilitation dollars are spent; and (3) provide an overview of typical values for maintenance frequencies and system reinvestment expense amounts to serve as benchmarks for local governments and agencies in evaluating their own programs. This project is funded by OW under its 104b3 Cooperative Agreement Program.

5.4 Sanitary Sewer System Design Practices

This project would review the appropriateness of current sanitary sewer system design practices. The following are some of the questions that could be answered: Are systems built to current design standards (e.g., systems in 5-year old development areas) experiencing excessive I/I? At what age do separate systems begin to experience excessive I/I? Should separate sewer systems construction design materials be comparable to those used in potable water design (systems which are not known to experience chronic widespread failure)? This project will be funded by NRMRL.

5.5 House Service Laterals

Approximately 70 to 80% of I/I comes from faulty house service laterals, especially from the coupling between the house service and street laterals due to differential settling of these laterals. This project will develop and evaluate new and improved coupling techniques and house service laterals in order to significantly alleviate I/I. This project will be funded by OW under its 104b3 Cooperative Agreement Program and NRMRL.

5.6 Reduced Impervious Cover

Reductions in urban and suburban impervious cover, e.g., roadways and parking lots has been shown to significantly reduce stormwater runoff quality and hydraulic impacts to surface waters. This project will develop methods and evaluate the benefits of reducing impervious area cover by such methods as: narrower roadways, porous pavements, zoning practices, and greenway buffers. This project will be funded by NRMRL.

5.7 Swales Instead of Curbs

Street curbs and gutters intensify the quantity of polluted stormwater runoff entering receiving water bodies. This project will evaluate the benefits (and disadvantages) of using side grass swales and other methods to take the place of curbs and gutters. This project will be funded by NRMRL.

6. Research Assistance

6.1 WWF Research Plan

The UWMB's WWF Program has developed a five-year research plan to conduct intramural and extramural research and to detail collaborative efforts with related EPA and other non-EPA programs. A presentation of the plan will be given at the 24th Annual ASCE Conference, Water Resources Planning and Management Division, April 7-10, 1997, Houston, Texas and published in the proceedings. In addition a peer-reviewed journal article of the plan will be submitted for potential publication. This plan will be updated annually, in coordination with OW. This project will be funded by NRMRL.

6.2 On-site Laboratory

The WWF Research Program will plan, design, install and operate an intramural laboratory. This laboratory will conduct research and analyses for the: (1) development of bench-scale WWF treatability procedures to significantly improve selection and design of full-scale WWF control systems, (2) development of streamlined watershed monitoring practices, including quick tests for determining limiting nutrients (nitrogen, phosphorus, carbon) causing eutrophication, especially in areas impacted by septic systems, (3) characterization of source contributions of WWF toxicsubstances as part of a pollution prevention strategy, and (4) characterization of the required particle size for adequate WWF disinfection. Other research efforts will be conducted in future years. This project will be funded by NRMRL.

6.3 WWF Training

Pertinent WWF Research Program, OWM Program, and water resources and treatment references will be made available and disseminated to bring intramural WWF staff rapidly up the learning curve. Reading material will be reinforced by a training films and animated computer presentations. Sessions would be scheduled for intramural WWF Program discussions and seminars on pertinent topics. Dr. Robert Pitt of the University of Alabama, an expert in stormwater research, conducted a three-day seminar in November 1995. Other WWF experts including Frank Rogella, Steve Hides, Dave Averill, and Dr. William Pisano have also given seminars. Depending on the level of funds for training, WWF Program staff members would also be able to attend extramural WWF conferences, seminars, and courses to enhance their knowledge in the WWF area. This project will be funded by NRMRL.

6.4 Support to the WERF

As a member of the Water Environment Research Foundation's (WERF's) Wet Weather Research Advisory Panel, the WWF Program represented by Richard Field provides detailed technical assistance for the development and management of WWF projects valued at millions of dollars. Much of the WERF-WWF program is supported by EPA 104(b)(3) cooperative agreements. This project is funded by NRMRL.

6.5 WERF Research Needs

The objectives of this project are to conduct a critical review of the status of existing information and valid scientific data and to identify areas of future research relative to wet weather runoff associated with urban watersheds. It is expected the assessment will concentrate on reviewing approaches to issues such as accumulation and transport of pollutants, ecosystem level effects of different BMPs and monitoring methods. The final report will be a comprehensive document which critically evaluates existing information pertaining to wet weather events and identifies areas of future research. This project will be funded by OW under its 104b3 Cooperative Agreement Program.

6.6 Annual Literature Review

The WWF Research Program will produce the 1996 through 2000 WWF annual literature reviews for *Water Environment Research*. The required literature searches will supplement research for WWF Research Program projects and training to the WWF staff while producing a prestigious deliverable. This project will be funded by NRMRL.

6.7 Stormwater Management Conference

The Conference will be an Engineering Foundation/Urban Water Resources Research Council Conference entitled, “Integrating Stormwater Quality & Quantity Management Into Sustainable Urban Water Resources Programs -- State-of-the-Art & Future Directions” will be held in Malmo, Sweden. “How do we pull it all together?”, “ Where do we go from here?”, and “How do we make it work?”, are the conference questions that support its theme of integration andimplementation. The conference will be funded by OW under its 104b3 Cooperative Agreement Program in support of funding by others.

6.8 Vortex Journal Article

Richard Field of the WWF Program has been invited by the Wastewater Technology Centre under Environment Canada (EPA’s Canadian counterpart) to be the principal author of a vortex separation concept paper. The paper was peer reviewed and will be published by the *Water Quality Research Journal of Canada* in January 1997. This project is funded by NRMRL.

6.9 Support to Environment Canada

Environment Canada is demonstrating a variety of pilot-scale, high-rate CSO treatment processes, e.g., a vortex separator, filtration, microscreens, and disinfection by UV. Richard Field of the WWF Program is participating as an expert advisor and is obtaining valuable evaluation data. A joint Environment Canada-NRMRL report will be published. Environment Canada’s cost for this project is estimated to be $1,500,000. This project is funded by NRMRL in support of principal funding by Environment Canada.

6.10 CSO Optimization Paper

CSO must be controlled by a storage-treatment system because storm flow in the combined sewerage system is intermittent and highly variable in both pollutant concentration and flowrate. A treatment facility operating without the benefit of upstream storage would need to be very large and costly in order to handle the relatively high flowrate of a CSO. Similarly, if storage is used without treatment, the storage volume required would be very large and also expensive. This paper describes a strategy to optimize CSO control system. This optimized system maximizes the use of the existing system before new construction and sizes the storage volume in concert with the WWTP treatment rate to obtain the lowest cost storage and treatment system. The paper was peer reviewed by the *Journal of the Environmental Engineering Division*, ASCE and will be published in March 1997. This project is funded by NRMRL.

6.11 Expanded Literature Review

Although this research plan has many references, given that it will be widely read, there are some important new references which should be included. For example, many EPA staff members are familiar with he fact that ASCE's Urban Water Resource Research Council, in conjunction with the Engineering Foundation and (frequently) the EPA, has held conferences on various facets of wet weather management every two to three years from the mid-1960s to the present. The last such conference was held in Snowbird, Utah in August 1996. Prior to the 1996 conference, an important conference was held in Crested Butte, Colorado in 1994 on stormwater monitoring needs. An excellent feature of the proceedings from these conferences is that they identify research needs in the wet weather arena. Interestingly, many of the research needs identified in the 1960s and 1970s continue to apply today. It would also be helpful if the next version of the *Wet Weather Research Needs* could reference books like the 1993 ASCE/WEF *Manual of Practice for the Design and Construction of Urban Stormwater Management Systems* and the soon to be published WEF/ASCE *Manual of Practice on Urban Stormwater Quality Management.* References of this kind have been written and reviewed by a wide variety of wet weather practitioners. The references carefully describe not only what we know but also what wedo *not* know. Consequently, it would be feasible to go through the books, identify the areas where design information is lacking, and add them to the list of research needs suggested by the EPA. This project will be funded by NRMRL.

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1994.**APPENDIX BWWF RESEARCH PROGRAM - FY97 FUNDING NOVEMBER 1996**

FY97 FUNDING (in thousands of dollars)										
Project Title		NRMRL Person Years (PYs)	NRMRL		104b3		Congressionally Mandated	ETV/ ETI	ORD Grants	Joint Funding
			Infrastructure	Extra-mural	OW	Region				
Research Area - Characterization and Problem Assessment										
1.1	Pathogen Detection									
1.2	Fecal Contamination								400[a]	
1.3	CSO Monitoring	0.2		45						
1.4	Receiving Water Impacts	0.3								
1.5	WWF Physical Stressors									
1.6	Urban Landfill Pollution									
1.7	Small Stream Impacts				230[a]					
1.8	Large River Pollution				500[a]					
1.9	Evaluation of Health Risks				300[a]					
1.10	Water Body Impacts Model									
1.11	Fate of Nitrogen Inputs							230[a]		
1.12	Influences of Land Use							500[a]		
1.13	CSO Disinfection	0.2	65	85						
Research Area - Watershed Management										

2.1	Watershed Management	0.8	83.1	175			
2.2	New Urban Areas	0.2			150		
2.3	Watershed Modeling	0.6	60	115			
2.4	Source Water Protection						15,000
2.5	Stormwater Reuse						
2.6	Stormwater-Groundwater Interactions	0.5		70			
2.7	Natural Attenuation						
2.8	Vadose Zone						
2.9	Atmospheric Deposition						
2.10	Mill Creek Watershed Plan				100[a]		
2.11	Catoma Creek Watershed Plan				100[a]		
2.12	Stormwater Control/Impacts						
2.13	Watershed Model-Case Study	0.2		75			
2.14	Watershed Ecosystem Model					330[a]	
2.15	WWF Information Repository	0.4	75	15			
2.16	Sediment Impacts and Control						
Research Area - Toxic Substances Impacts and Control							

3.1	Toxics' Characterization/Treatment	0.3		100			
3.2	Toxics' Testing/Assessment						
3.3	Toxics' Pollution Prevention	0.4		200			
3.4	Natural-Fiber Filtration	0.1					
3.5	Toxics' Risk Assessment						leveraged
Research Area - Control Technologies							
4.1	Rouge River Restoration					47,000[a]	
4.2	BMP Manual	0.5					
4.3	Industrial Runoff Control						
4.4	Management for Small Communities						
4.5	Roadway/Airport Deicing						
4.6	BMP Design/Effectiveness	0.1			30		leveraged
4.7	Urban BMP Effectiveness				225		
4.8	Runoff Control Using Compost	0.1		70			
4.9	Riparian Forest Management						
4.10	CSO Measures of Success				150[a]		
4.11	Flow Balance Method	0.2					leveraged
4.12	Storm Inlet Device	0.3	45				

4.13	Stormceptor’s Storm Inlet Device			
4.14	CDS Stormwater Treatment			
4.15	Cross Connection Identification	0.1		
4.16	Storage Facilities Design	0.1		75
4.17	Real-Time Control by Radar	0.1		75
4.18	CSO Vortex Controls			
4.19	High-Rate Sedimentation	1.0	50	50
4.20	Magnetic Separation			
4.21	WWF Design Protocols	1.5	75	101.9
4.22	Retrofitting Control Facilities	0.1		
4.23	CSO Concepts for Stormwater	0.1		
4.24	SSO Corrective Action	0.5		75
4.25	Impacts/Effectiveness Protocols			135[a]
4.26	Vortex/Disinfection Treatment	0.1		
4.27	Crossflow Plate Settlers			
4.28	High-Rate Disinfection	0.3		75
4.29	Demonstration of Biofilters			

4.30	High-Rate Ozonation						
4.31	Triple Purpose Storage						
4.32	Harlem River Wetlands	0.1		30			leveraged[b]
4.33	Storage/Wetlands Treatment					100[a]	leveraged
4.34	Constructed Vegetative Treatment Cells						
4.35	ETV Pilot for WWF Control Systems					800	
4.36	Sewer and Tank Sediment Flushing	0.2	50				
Resarch Area - Infrastructure Improvement							
5.1	Infrastructure Rehabilitation						
5.2	Sewer Maintenance Effectiveness				120		
5.3	Sewer Maintenance Optimization				150		
5.4	Sanitary Sewer System Design Practices						
5.5	House Service Laterals						
5.6	Reduced Impervious Cover			50			
5.7	Swales Instead of Curbs			30			
Resarch Area - Research Assistance							
6.1	WWF Research Plan	0.2					

6.2	On-Site Laboratory	0.7	80							
6.3	WWF Training	1.0	15							
6.4	Support to the WERF	0.1								
6.5	WERF Research Needs									
6.6	Annual Literature Review	0.2								
6.7	Stormwater Management Conference	0.1			25					
6.8	Vortex Journal Article									
6.9	Support to Environment Canada	0.1								
6.10	CSO Optimization Paper									
6.11	Expanded Literature Review									
Totals		12.2	598.1	1646.9	2080	0	47000	1630	730	15000

[a] Reflects FY97 and previeous funding [b] Federal Highway Administration Grant Funding